THE

OPERATIVE MECHANIC'S

)RKSHOP COMPANION,

AND

HE SCIENTIFIC GENTLEMAN'S

Practical Assistant:

COMPRISING

REAT VARIETY OF THE MOST USEFUL RULES IN
MECHANICAL SCIENCE,

DIVESTED OF MATHEMATICAL COMPLEXITY;

umerous Tables of Practical Data and Calculated Results,
facilitating Mechanical and Commercial Transactions.

BY W. TEMPLETON,
AUTHOR OF SEVERAL SCIENTIFIC WORKS.

THIRD EDITION, WITH THE ADDITION OF
:HANICAL TABLES FOR THE USE OF OPERATIVE
SMITHS, MILLWRIGHTS, AND ENGINEERS;
AND
CAL DIRECTIONS FOR THE SMELTING OF METALLIC ORES.

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TO THE PUBLIC.

The subjects of the following pages are chiefly compiled at the instigation of pressing solicitations by numerous individuals, no few of whom complain of the want of a convenient Text Book of Reference in which Mechanical and Commercial demands are judiciously combined. Others, with apparently equal reasons, for the sake of instruction, complain of the want of a compendium in which tuition and practical reference are discriminately arranged; and generally, that for purposes of estimation, no properly portable work is yet in existence: hence it is with a wish to diminish those wants in some degree that the present attempt has been made to supply the necessary information.

In regard to the selection, great care has been taken that the subjects be not only intimately interwoven, but also of such a nature as business transactions call most frequently into requisition. The elementary or educational portion will be found exceedingly plain, simple, and aptly adapted; also the practical rules much abbreviated through the application of decimal approximates, by which results are obtained sufficiently exact, and the means of calculation considerably facilitated.

That the production might be rendered still mc worthy of public patronage, numerous diagrams, a several engravings, are annexed, which add much its value in regard to practical utility; and it oı remains to add the hope, that the Operative, t Man of Science, and an interested Public, may gi due appreciation to the work, in proportion to merits.

W. T

The present edition has been much extended the insertion of numerous Tables for the use Operative Smiths, Millwrights, and Engineers, a by a further addition of Practical Observations the Smelting of Metallic Ores.

Nov. 16, 1852.

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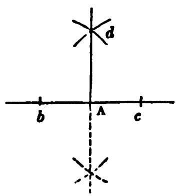
PRACTICAL GEOMETRY.

GEOMETRY is the science which investigates and demonstrates the properties of lines on surfaces and solids: hence, PRACTICAL GEOMETRY is the method of applying the rules of the science to practical purposes.

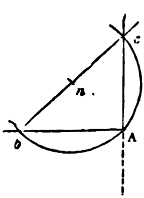
1. *From any given point, in a straight line, to erect a perpendicular; or, to make a line at right angles with a given line.*

On each side of the point A from which the line is to be made, take equal distances, as A *b*, A *c*; and from *b* and *c* as centres, with any distance greater than *b* A, or *c* A, describe arcs cutting each other at *d*; join A *d*, which will be the perpendicular required.

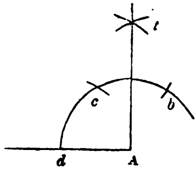


2. *When a perpendicular is to be made at or near the end of a given line.*

Take any point *n* above A *b*, and with centre *n* and distance *n* A, describe a circle, cutting the given line at *b*; through *b* and the centre *n*, draw the diameter *b n c*, and join *c* A, which will be the perpendicular required.



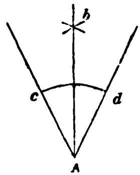
3. *To do the same otherwise.*



From the given point A, with any convenient radius, describe the arc *d c b*; with the same radius from *d*, cut the arc in *c*, and from *c*, cut the arc in *b*; also from *c* and *b* as centres, with the same or any other radius, describe arcs cutting each other in *t*; then will the line A *t* be the perpendicular required.

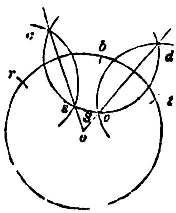
Note.—When the three sides of a triangle are in the proportion of 3, 4, and 5 equal parts respectively, two of the sides form a right angle; and observe that in each of the preceding problems, the perpendiculars may be continued below the given lines, if necessarily required.

4. *To bisect any given angle.*



From the point A as a centre, with any radius less than the extent of the angle, describe an arc, as *c d*; and from *c* and *d* as centres, describe arcs cutting each other at *b*; then will the line A *b* bisect the angle as required.

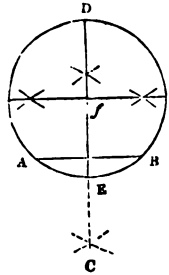
5. *To find the centre of a circle that shall cut any three given points, not in a direct line.*



From the middle point *b* as a centre, with any radius, as *b c*, *b d*, describe a portion of a circle, as *c s d*; and from *r* and *t* as centres, with an equal radius, cut the portion of the circle in *c*, *s* and *d*, *v*; draw lines through where the arcs cut each other, and the

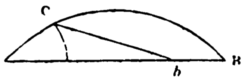
intersection of the lines at *o* is the centre of the circle required.

6. *To find the centre of a given circle.*



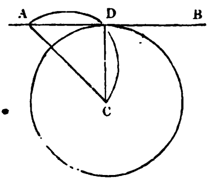
Bisect any chord in the circle, as A B, by a perpendicular C D; bisect also the diameter E D in *f*, and the intersection of the lines at *f* is the centre of the circle required.

7. *To find the length of any given arc of a circle.*



With the radius A C, equal to $\frac{1}{4}$th the length of the chord of the arc A B, and from A as a centre, cut the arc in C; also from B as a centre, with equal radius, cut the chord in *b*; draw the line C *b*, and twice the length of the line is the length of the arc nearly.

8. *Through any given point, to draw a tangent to a circle.*

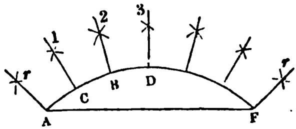


Let the given point be at A; draw the line A C, on which describe the semicircle A D C; join A D, which, produced if necessary, is the tangent required.

9. *To draw from, or to the circumference of a circle,*

lines tending towards the centre, when the centre is inaccessible.

Divide the whole or any given portion of the circumference into the desired number of equal parts; then with any radius less than the distance of two divisions, describe arcs cutting each other, as A 1, B 1, C 2, D 2, &c.; draw the lines C 1, B 2, D 3, &c., which lead to the centre as required.

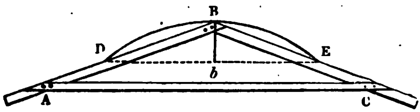


To draw the end lines,

As A *r*, F *r*, from C describe the arc *r*, and with the radius C 1, from A or F as centres, cut the former arcs at *r*, or *r*, and the lines A *r*, F *r*, will tend to the centre as required.

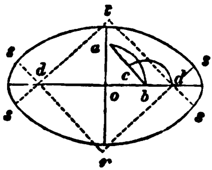
10. *On a given straight line, to describe an arc of a circle, the altitude being given.*

Let D E be the given straight line, B *b* the given altitude: join D B, B E, and of any suitable material



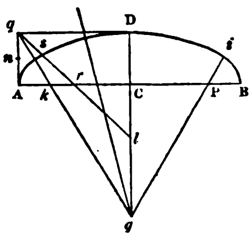
construct a triangle, as A B C, making each of the sides A B, B C, equal at least to the chord D E, and the angle contained by them equal to D B E; at each end of the chord D E, fix a pin, and at B a tracer, as a pencil; move the triangle along the pins as guides, and the tracer will describe the arc required.

11. *To describe an ellipse, having the two diameters given.*



On the intersection of the two diameters as a centre, with a radius equal to the difference of the semi-diameters, describe the arc *a b*, and from *b* as a centre, with half the chord *b c a*, describe the arc *c d*; from *o*, as a centre, with the distance *o d*, cut the diameters in *d*, *r*, *d*, *t*; draw the lines *r s*, *r s*, *t s*, *t s*, then from *r* and *t* describe the arcs *s s*, *s s*; also from *d* and *d* describe the smaller arcs *s s*, *s s*, which will complete the ellipse as required.

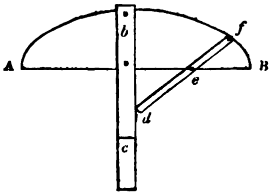
12. *To describe an elliptic arch, the width and rise of span being given.*



Bisect with a line at right angles the chord or span A B, erect the perpendicular A *q*, and draw the line *q* D equal and parallel to A C; bisect A C and A *q* in *r* and *n*, make C *l* equal to C D, and draw the line *l r q*; draw also the line *n s* D; bisect *s* D with a line at right angles, and meeting the line C D produced in *g*; draw the line *g q*, make C P equal to C *k*, and draw the line *g* P *i*; then from *g* as a centre, with the radius *g* D, describe the arc *s* D *i*, and from *k* and P as centres, with the radius A *k*, describe the arcs A *s* and B *i*, which completes the arch as required. *Or,*

13. Bisect the chord A B, and fix at right angles any straight guide, as *b c*; prepare of any suitable

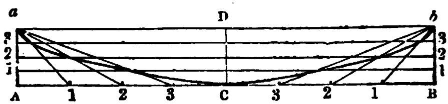
material a rod or staff, equal to half the chord's length, as *d e f*; from the end of the staff, equal to the height of the arch, fix a pin *e*, and at the extremity a tracer *f*; move the staff, keeping its end



to the guide and the fixed pin to the chord, and the tracer will describe one-half the arch required.

14. *To describe a parabola, the dimensions being given.*

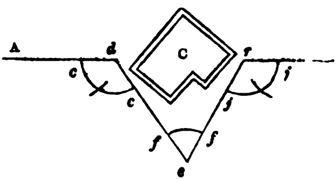
Let A B equal the length, and C D the breadth of the required parabola: divide C A, C B into any



number of equal parts, also divide the perpendiculars A *a* and B *b* into the same number of equal parts; then from *a* and *b* draw lines meeting each division on the line A C B, and a curve line drawn through each intersection will form the parabola required.

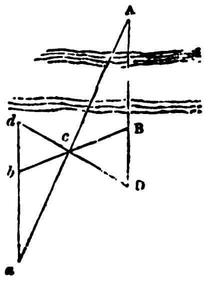
15. *To obtain by measurement the length of any direct line, though intercepted by some material object.*

Suppose the distance between A and B is required, but the right line is intercepted by the object C. On the point *d*, with any



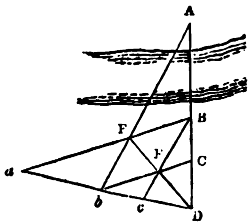
convenient radius, describe the arc *c c*, make the arc twice the radius in length, through which draw the line *d c e*, and on *e* describe another arc equal in length to once the radius, as *e f f*; draw the line *e f r* equal to *e f d*; on *r* describe the arc *j j*, in length twice the radius; continue the line through *r*, *j*, which will be a right line, and *d e*, or *e r*, will equal the distance between *d*, *r*, by which the distance between A and B is obtained as required.

16. *To ascertain the distance geometrically, of any inaccessible object on an equal plane.*



Let it be required to find the distance between A and B, A being inaccessible: produce the line in the direction of A B to any point, as D; draw the line D *d* at any angle to the line A B; bisect the line D *d* in *c*, through which draw the line B *b*, making *c b* equal to B *c*; join A *c*, and draw *d b a* meeting A *c*, produced in *a*. Then *b a*, equal to A B, is the distance required.

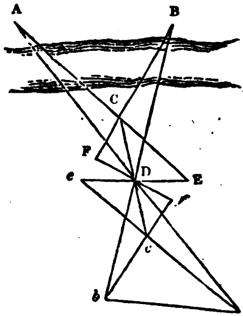
17. *Or otherwise,*



Produce A B to any point D, and bisect B D in C; through D draw D *a*, making any angle with D A, and take D *c*, D *b*, equal to D C and D B respectively; join B *c*, C *b*, and A *b*. Through E, the intersection of B *c*, C *b*, draw D E F meeting A *b* in

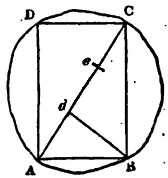
F; join B F, which being produced will meet D *a* in *a*. Then *a b* is equal to A B, the distance required.

18. *To measure the distance between two objects, both being inaccessible.*



From any point C draw any line C *c*, and bisect it in D; take any point E in the prolongation of A C, and draw the line E *e*, making D *e* equal to D E; in like manner take any point F in the prolongation of B C, and make D *f* equal to F D. Produce A D and *e c* till they meet in *a*, and also B D and *f c* till they meet in *b*; then *a b* is equal to A B, or the distance between the objects as required.

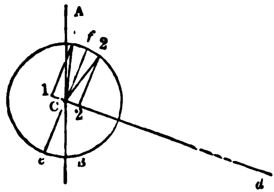
19. *A round piece of timber being given, out of which to cut a beam of strongest section.*



Divide into three equal parts any diameter in the circle, as A *d*, *e* C; from *d* or *e*, erect a perpendicular meeting the circumference of the circle, as *d* B; draw A B and B C, also A D equal to B C, and D C equal to A B, and the rectangle will be a section of the beam as required.

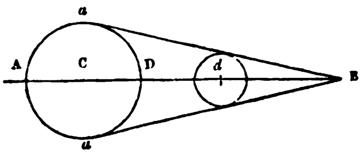
20. *To find the proper position for an eccentric, in relation to the crank in a steam engine, the angle*

of eccentric rod and travel of the valve being given.

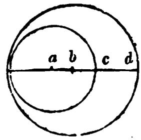


Draw the right line A B, as the situation of the crank at commencement of the stroke; draw also the line C *d*, as the proper given angle of eccentric rod with the crank; then from C as centre, describe a circle equal to the travel of the valve; draw the line *e f* at right angles to the line C *d*; draw also the lines 1 1, and 2 2, parallel to the line *e f*; and at a distance from *e f* on each side, equal to the lap and lead of the valve, draw the angular lines C 1, C 2, which are the angles of eccentric with the crank, for forward or backward motion, as may be required.

21. *The throw of an eccentric, and the travel of the valve in a steam engine, also the length of one lever for communicating motion to the valve, being given, to determine the proper length for the other.*



On any right line, as A B, describe a circle A D, equal to the throw of eccentric & travel of valve; then from C as a centre, with a radius equal to the length of lever given, cut the line A B, as at *d*, on which describe a circle, equal to the throw of eccentric or travel of valve, as may be required; draw the tangents B *a*, B *a*, cutting each other in the line A B, and *d* B is the length of the lever as required.

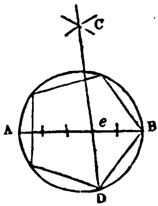


Note.—The throw of an eccentric is equal to the sum of twice the distance between the centres of formation and revolution, as *a b*, or to the degree of eccentricity it is made to describe, as *c d*. And

The travel of a valve is equal to the sum of the widths of the two steam openings, and the valve's excess of length more than just sufficient to cover the openings.

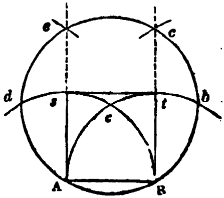
22. *To inscribe any regular polygon in a given circle.*

Divide any diameter, as A B, into so many equal parts as the polygon is required to have sides; from A and B as centres, with a radius equal to the diameter, describe arcs cutting each other in C; draw the line C D through *e*, the second point of division on the diameter, and the line D B is one side of the polygon required.

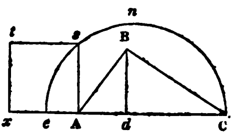


23. *To construct a square upon a given right line.*

From A and B as centres, with the radius A B, describe the arcs A *c b*, B *c d*, and from *c* with an equal radius describe the circle or portion of a circle *e d* A B *b c*; from *b*, *d*, cut the circle at *e* and *c*; draw the lines A *e*, B *c*, also the line *s t*, which completes the square as required.



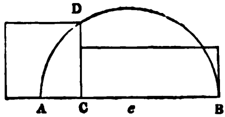
24. *To form a square equal in area to a given triangle.*



Let A B C be the given triangle: let fall the perpendicular B *d*, and make A *e* half the height *d* B; bisect *e* C,

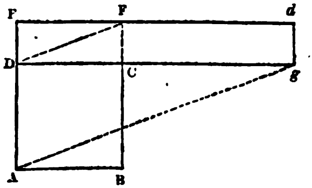
and describe the semicircle *e n* C; erect the perpendicular A *s*, or side of the square, then A *s t x* is the square of equal area as required.

25. *To form a square equal in area to a given rectangle.*



Let the line A B equal the length and breadth of the given rectangle: bisect the line in *e*, and describe the semicircle A D B; then from A with the breadth, or from B with the length of the rectangle, cut the line A B at C, and erect the perpendicular C D, meeting the curve at D, and C D is equal to a side of the square required.

26. *To find the length for a rectangle whose area shall be equal to that of a given square, the breadth of the rectangle being also given.*

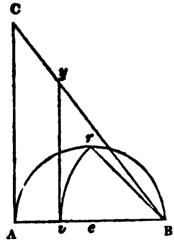


Let A B C D be the given square, and D E the given breadth of rectangle. Through E draw E F parallel to A B or D C; produce B C to F, and join D F. Through A draw A *g* parallel to D F, cutting D C produced in *g*, through which draw *g d* parallel to D E, meeting E F produced in *d*. E D *g d* is the rectangle required.

27. *To bisect any given triangle.*

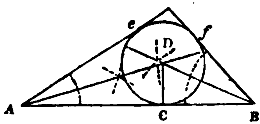
Suppose A B C the given triangle: bisect one of

its sides, as A B in *e*, from which describe the semicircle A *r* B; bisect the same in *r*, and from B, with the distance B *r*, cut the diameter A B in *v*; draw the line *v y* parallel to A C, which will bisect the triangle as required.



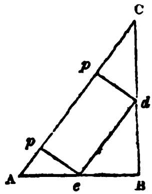
28. *To describe a circle of greatest diameter in a given triangle.*

Bisect the angles A and B, and draw the intersecting lines A D, B D, cutting each other in D; then from D as centre, with the distance D C, which is drawn perpendicular to A B, describe the circle C *e f*, as required.



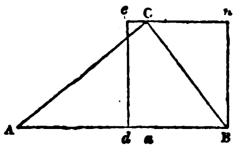
29. *To form a rectangle of greatest surface, in a given triangle.*

Let A B C be the given triangle: bisect any two of its sides, as A B, B C, in *e* and *d*; draw the line *e d*; also at right angles with the line *e d*, draw the lines *ep*, *dp*, and *e p p d* is the rectangle required.

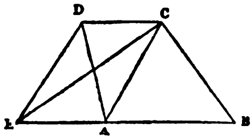


30. *To make a rectangle equal to a given triangle.*

Suppose A B C the given triangle: bisect A B in *d*, and erect the perpendicular *d e*; erect also the perpendicular B *n*; through C draw the line *e* C *n* parallel to A B, meeting *the above in e* and *n* respec-*tively; then e d* B *n* is the rectangle as required.

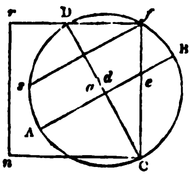


31. *To make a triangle equal to a given quadrilateral, as* A B C D.



Prolong the line B A, and draw the line A C; draw also the line D E parallel to A C, and cutting the line B A in E; then draw the line E C, and C E B is the triangle required.

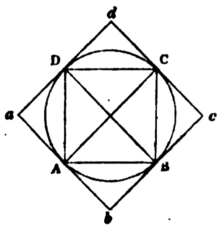
32. *To form a square nearly equal in area to a given circle.*



Let A C B D be the given circle: draw the diameters A B and C D at right angles to each other, bisect the radius *d* B in *e*, and draw the line C *e f*; draw also at right angles the lines C *n* and *f r*, making each equal to C *f*; join *n r*, and *n* C *f r* is the square as required.

Note.—The line *s f* is equal to one-fourth the circumference of the circle.

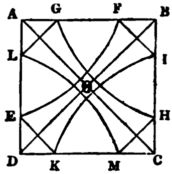
33. *To inscribe or describe a square within or without a given circle: also to form an octagon from a given square.*



1. Let A B C D be the given circle: draw the diameters A C, B D, at right angles to each other, and join A B, B C, C D, D A, which will complete the inscribed square: through the extremities of the same diameters draw *a b*, *c d*, parallel

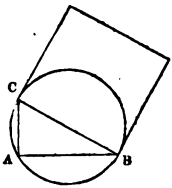
to B D, and *a d, b c,* parallel to A C, which will complete the square equal in breadth to the diameter of the circle.

2. Let A B C D be the given square. Draw the two diagonal lines A C and B D intersecting in O; then with a radius equal to A O, or half the diagonal, and with A as a centre, describe the arc E F, cutting the sides of the square in E and F; then from B as a centre, describe the arc G H, and in the same manner from C and D describe the arcs I K and L M. Draw the lines L G, F I, H M, and K E, which, with the parts G F, I H, M K, and E L, form the octagon required.



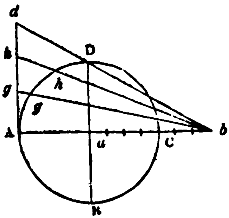
34. *To form a square equal to two given squares, or, a circle equal to two given circles.*

Let A B, A C, equal the sides of the given squares, or diameters of the given circles: make the angle at A a right angle, and draw the line C B, which is the side of a square equal to both the given squares; or bisect the line C B as a diameter, on which describe the circle C B A, which is equal to the two given circles as required.



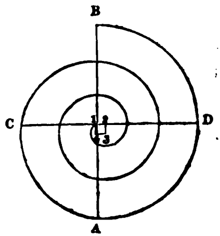
35. *To draw a right line equal to any given portion of the circumference of a circle.*

Let A B C D be a given circle, the whole circum-



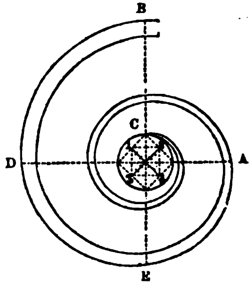
ference of which is required: draw at right angles the diameters A C, B D, divide the radius *a* C into four equal parts, and make C *b* equal to three of them; draw the tangent A *d* parallel to B D, draw the line *b* D *d*, then will A *d* equal one-fourth of the whole circumference; and if lines be drawn from *b*, through points in the circumference, meeting the line A *d*, as *g g*, *h h*, &c., the corresponding parts will be equal to each other.

36. *To draw a spiral with spaces of uniform distance.*



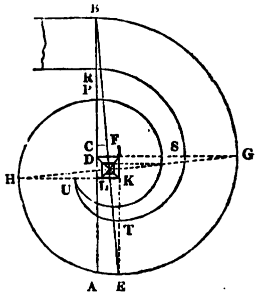
Bisect the height of the spiral, as A B, and divide either half into the number of spaces or revolutions required; then again subdivide any one space into four equal parts, one of which add to half the height of the spiral, and through which draw the line C D at right angles to A B, thus forming the centre of the spiral, around which and equal to one of the subdivisions form a square, its sides being parallel with the lines A B and C D, the angles of which are the centres from whence to describe the various curves; as from 1, with the distance 1 B, describe the curve B D; from 2, with the distance 2 D, describe D A; from 3, with the distance 3 A, describe A C, &c., &c., and from the same centres the spiral may be continued to any extent required.

37. *To draw a volute for the capital of the Ionic column.*



Draw at right angles C A, C B, and on the centre C describe a circle equal to one-fourth of the height C B; form a square in the circle, the diagonals of which correspond with or cut the diameters A D, E B; bisect the square with lines crossing each other in the centre C, and parallel with the sides of the square; divide each into six equal parts, which are the centres from which the volute is to be described: thus, from 1, with the distance 1 B, describe the curve B D; from 2, with 2 D, describe D E; from 3, with 3 E, describe E A, &c., approaching the centre by degrees until the volute is completed as required.

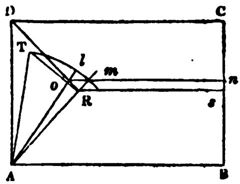
38. *To draw a scroll for the termination of a hand-rail, &c.*



Let A B equal the given breadth: draw A E perpendicular to A B, which divide into eleven equal parts, and A E equal to one of them; join B E, bisect A B in C and B E in F, make C D equal to C F, and draw D G perpendicular to A B; from F, with the radius F E, or F B, describe an arc cutting D G at G; draw G H perpendicular to B E, cutting B E at O (or centre of the scroll); draw the diagonals

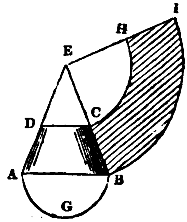
D O K, I O L, perpendicular to D O K; draw I K parallel to B A, K L parallel to I D, &c., meeting the diagonals; from D as a centre, with the distance D B, describe the arc B G; from I as a centre, with the distance I G, describe G E; from K, with the distance K E, describe K H, &c., proceeding in the same manner until the outside of the scroll is completed; make B R equal to the breadth of the rail; then from D, with the distance D R, describe the arc R S; from I, and distance I S, describe S T; and from T, with K T, describe T U, which completes the scroll as required.

39. *To find the various angles and proper dimensions of materials whereby to construct any figure whose form is the frustum of a proper or inverted pyramid, as hipped roofs, mill hoppers, &c., &c.*

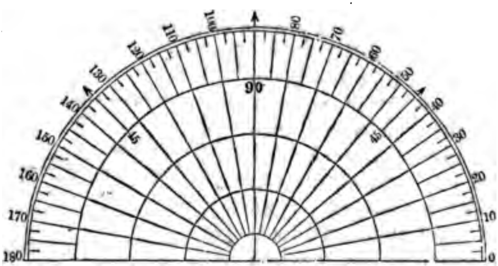


Let A B C D be the given dimensions of plan for a roof, the height R T also being given; draw the diagonal A R, meeting the top or ridge R *s* on plan; from R, at right angles with A R and equal to the required height, draw the line R T, then T A, equal the length of the struts or corners of the roof; from A, with the distance A T, describe an arc T *l*, continue the diagonal A R until it cuts the arc T *l*, through which, and parallel with the ridge R *s*, draw the line *m n*, which determines the required breadth for each side of the roof: from A, meeting the line *m n*, draw the line A *o*, or proper angle for the end of each board by which the roof might require to be covered; and the angle at T is what the boards require to be made in the direction of their thickness, when the corners or angles require to be mitred.

40. *To describe the proper form of flat plate by which to construct any given frustum of a cone.*



Let A B C D represent the required frustum: continue the lines A D and B C until they meet at E; then from E as centre, with the radius E C, describe the arc C H; also from E, with the radius E B, describe the arc B I; make B I equal in length to twice A G B, draw the line E I, and B C I H is the form of plate as required.



Sector from which angles may be obtained.

GEOMETRY APPLIED TO MECHANICS.

41. *To delineate a vee-threaded screw, the pitch and diameter of the screw being given.* (See Plate A, fig. 1.)

Upon the end of the line, or vertical centre of the screw A B, describe the semicircles C D, *c d*, the one being equal to the greatest diameter of the screw, and the other to the lesser diameter, or diameter at the bottom of the threads; divide each semi-circumference

Fig. 2.

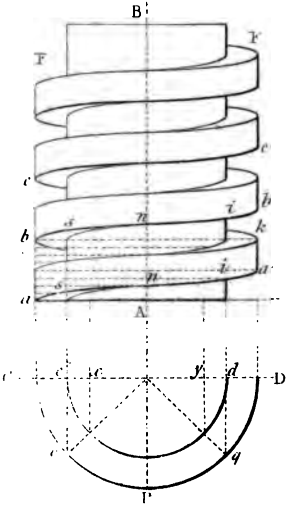


Fig. 3.

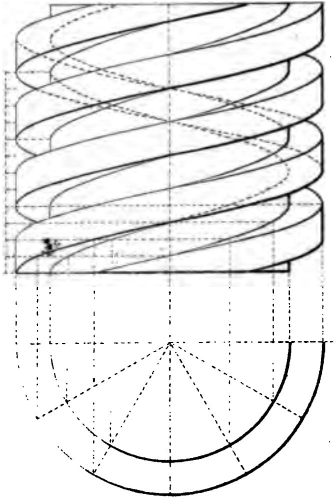
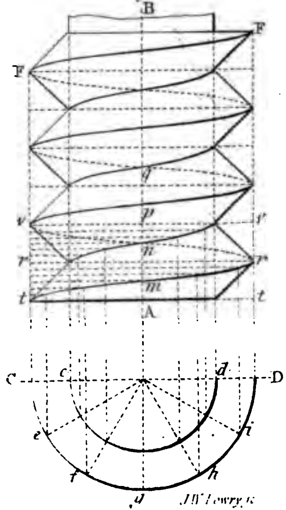


Fig. 1.



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into any number of equal parts, as C, *e*, *f*, *g*, *h*, *i*, D, from which draw lines parallel to the line A B; divide the lines C F, D F, into equal divisions of half the required pitch or consecutive threads, as *t*, *r*, *v*, &c.; draw the lines *t t*, *r r*, *v v*, &c., parallel with the diameter C D, and subdivide any two connected divisions into the same number of equal parts contained in both semicircles, from which draw lines meeting the vertical lines; then by hand, or otherwise, and through the intersections, draw the waved lines, *m*, *n*, *p*, *q*, &c., and a thread of the screw is delineated as required.

Note.—The same process might be continued throughout the whole length of the screw, but it is much more convenient, when the proper curves are obtained, to form a suitable ruler: lay it in its proper situation upon each division, and draw the lines as required.

42. *To delineate a square-threaded screw, the pitch and diameter of screw being given.* (See Plate A, fig. 2.)

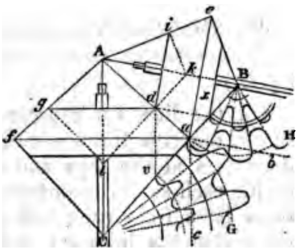
On the line A B representing the centre of the screw, describe the semicircles C D, *c d*, equal to the diameters at the tops and bottoms of the threads; divide each semi-circumference into four equal parts, draw lines from each and parallel to the line A B; draw also the lines C F, D F, which divide into the proper required pitch, as *a a*, *b b*, *e e*, &c.; divide any two connected pitches or divisions, as *a*, *b*, into four equal parts, from which draw lines parallel to the diameter C D, meeting the vertical lines *o*, *p*, *q*, and forming intersections through which the waved lines *s*, *n*, *i*, *s*, *n*, *i*, or tops of the threads, must be traced by hand or otherwise; draw also the lines *x*, *y*, forming intersections through which to trace the curve surface exhibited between and caused by the angular return

of the thread; describe also the curves *k* and *b*, which terminates the returning thread, and completes the delineation as required.

Fig. 3, as to mode of construction, is exactly similar to that of fig. 2, but intended, by displacement of the cylinder, to delineate a continuous vein of the spiral in its proper form around the whole circumference: hence, being deemed by the preceding figure already sufficiently described, further elucidation must be considered unnecessary.

43. *To determine the proper forms for a pair of bevel wheels, the required angle of the shafts and diameters of the wheels being given.*

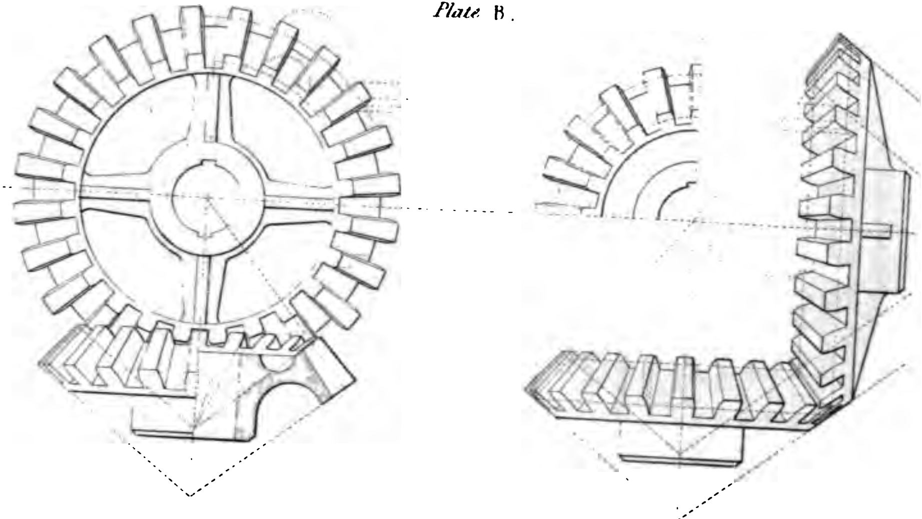
Draw at the given angles lines representing the shafts on which the wheels are to be fixed, as A B, A C; make the lines *a b*, *a c*, parallel with and at a distance from A B, A C, equal to the radius of each respective wheel at the greatest pitch circle; draw the line A *a* through the intersection at *d*; then from *a* at right angles



with A B, A C, draw the lines *a e*, *a f*, making each in length equal to the wheel's diameter; draw the lines A *e*, A *f*, and from *a*, with the intended breadth of the wheels on the face, cut the line A *a* in *d*; draw the lines *d i*, *d g*, parallel to *a e*, *a f*, (hence the proper conical forms of the wheels and the pitch circles;) draw at right angles with A *a*, and through the intersection of the lines *a e*, *a f*, the line C B, also the lines B *e*, *c f*, *d k i*, *d l g*; from B and C, with

[illegible] THE DRAWING OF BEVEL WHEELS.

Plate B.



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the radius B a, C a, describe portions of circles, as a G, a H, on which describe the greatest dimensions of, and proper form of the teeth; then from d, and parallel with A B, A C, draw the lines $a\,v$, $a\,x$, cutting the line C B in v and x; from B and C, with the distances C v, B x, describe the portions of circles, which determines the dimensions of the teeth on the interior pitch circle, and completes the proper forms of the wheels as required.

Proportions for the construction of toothed wheels.

Length of the teeth = $\frac{5}{7}$ of the pitch.
Thickness ,, = $\frac{4}{9}$ do.
Breadth on face = $2\frac{1}{2}$ times the pitch.

$\left.\begin{array}{l}\text{Edge of the rim}\\ \text{Projecting rib inside do.}\\ \text{Thickness of flat arms}\end{array}\right\}$ each $\frac{4}{9}$ of the pitch.

Breadth of arms at rim = 2 teeth and $\frac{1}{4}$ the pitch, increasing in breadth towards the centre of the wheel, in the proportion of $\frac{1}{2}$ an inch for every foot in length.

Thickness of the ribs or feathers on the arms = $\frac{1}{4}$ of the pitch.

Thickness of metal around the eye, or centre, = $\frac{7}{9}$ of the pitch.

Wheels and other circular bodies are very conveniently transferred from plan to that of a projected perspective by means of a peculiar appropriation of straight lines, commonly called orthographic projection, the principle of which will be readily understood by reference to the diagrams and illustrations given for the purpose in Plate C.

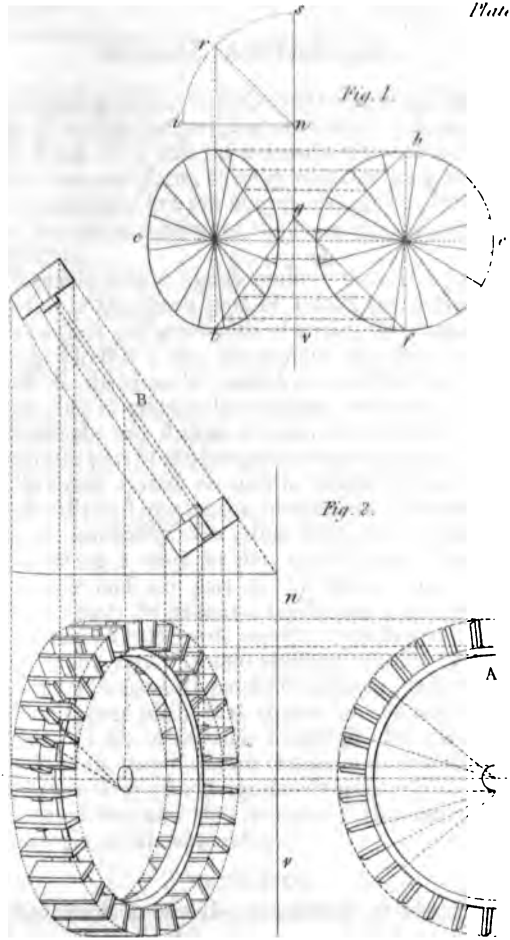
Fig. 1 is a circle divided into equal parts, and its form in projection is required, $v\,n$ being supposed the line of intersection: parallel with the diameter of the

circle *b f*, draw at right angles, and through the centre, the line *c e*; draw also the line or chord *f g*, cutting the line *v n* in *g*; then, with the distance *v g*, describe the quadrant *i r s*; bisect the arc in *r*, from which and parallel with *v n*, draw the line *r t*; draw also the lines *f t*, *g t*, which determines the breadth of the ellipsis or projected form of the circle, and which may be drawn as described (page 5, fig. 12): hence all the other lines being so distinctly described, by mere inspection of the diagrams, further explanation is unnecessary.

Fig. 2 is a projected representation of an undershot water-wheel, of which A is the plan, *v n* the line of intersection, and B the diameter and breadth, laid at a proper angle or inclination, as determined by the principles of the diagrams: the breadth of the ellipsis is found and formed as there described, and the lines in the illustration, or fig. 2, whereby to obtain the proper angles for projection, render sufficiently explicit the proper mode by which the representation is effected.

ORTHOGRAPHIC PROJECTION.

Plate C.



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DECIMAL ARITHMETIC.

Decimal Arithmetic is the most simple and explicit mode of performing practical calculations; on account of its doing away with the necessity of fractional parts in the fractional form, thereby reducing long and tedious operations to a few figures, arranged and worked in all respects according to the usual rules of common arithmetic.

Decimals simply signify tenths: thus, the decimal of a foot is the tenth part of a foot, the decimal of that tenth is the hundredth of a foot, the decimal of that hundredth is the thousandth of a foot, and so might the divisions be carried on and lessened to infinity; but in practice it is seldom necessary to take into account any degree of less measure than a one-hundredth part of the integer or whole number. And, as the entire system consists in supposing the whole number divided into tenths, hundredths, thousandths, &c., no peculiarity of notation is required, otherwise than placing a mark or dot, to distinguish between the whole and any part of the whole: thus 34·25 gallons signify 34 gallons 2 tenths and 5 hundredths of a gallon; 11·04 yards signify 11 yards and 4 hundredths of a yard; 16·008 shillings signify 16 shillings and 8 thousandth parts of a shilling: from which it must appear plain, that ciphers on the right hand of decimals are of no value whatever; but placed on the left hand, they diminish the decimal value in a tenfold proportion,—for ·6 signifies 6 tenths; ·06 signifies 6 hundredths; and ·006 signifies 6 thousandths, of the integer or whole number.

REDUCTION.

Reduction means the construing or changing of

vulgar fractions to decimals of equal value; also finding the fractional value of any decimal given.

Rule 1. Add to the numerator of the fraction any number of ciphers at pleasure, divide the sum by the denominator, and the quotient is the decimal of equivalent value.

Rule 2. Multiply the given decimal by the various fractional denominations of the integer or whole number, cutting off from the right hand of each product for decimals a number of figures equal to the given number of decimals, and thus proceed until the lowest degree, or required value, is obtained.

Ex. 1. Required the decimal equivalent, or decimal of equal value, to $\frac{3}{12}$ of a foot.

$$\frac{3\cdot00}{12} = \cdot25, \text{ the decimal required.}$$

Ex. 2. Reduce the fraction $\frac{1}{8}$ of an inch to a decimal of equal value.

$$\frac{1\cdot000}{8} = \cdot125, \text{ the decimal required.}$$

Ex. 3. What is the decimal equivalent to $\frac{7}{8}$ of a gallon?

$$\frac{7\cdot000}{8} = \cdot875, \text{ the decimal equivalent.}$$

Ex. 4. Required the value of the decimal ·40625 of an inch.

$$\begin{array}{lr} & \cdot40625 \\ \text{Multiply by } \frac{1}{8} & 8 \\ \hline & 3\cdot25000 \\ \times \frac{2}{16} = \frac{1}{8} & 2 \\ \hline & \cdot50000 \\ \times \frac{2}{32} = \frac{1}{16} & 2 \\ \hline & 1\cdot00000 \end{array}$$

$\frac{3}{8}$ and $\frac{1}{32}$ of an inch, the value required.

Ex. 5. What is the value of ·625 of a cwt.?

	·625
Multiply by 4 qrs.	4
	2·500
× 28 lbs.	28
	14·000 = 2 quarters and 14 lbs., the value required.

Ex. 6. Ascertain the value of ·875 of an imperial gallon.

	·875
Multiply by 4 quarts	4
	3·500
× 2 pints	2
	1·000 = 3 quarts and 1 pint, the value required.

Ex. 7. What is the value of ·525 of a £. sterling?

	·525
Multiply by 20 sh.	20
	10·500
× 12 pence	12
	6·000 = 10 shillings and 6 pence, the value required.

Independent of the mark or dot which distinguishes between integers and decimals, the fundamental rules, viz., Addition, Subtraction, Multiplication, and Division, are in all respects the same as in Simple Arithmetic; and an example in each, illustrative of placing the separating point, will no doubt render the whole system sufficiently intelligible, even to the dullest capacity.

Ex. 1. Add into one sum the following integers and decimals.

16·625; 11·4; 20·7831; 12·125; 8·04; and 7·002.

```
16·625
11·4
20·7831
12·125
 8·04
 7·002
-------
75·9751 = the sum required.
```

Ex. 2. Subtract 119·80764 from 234·98276.

```
234·98276
119·80764
---------
115·17512 = the remainder required.
```

Ex. 3. Multiply 62·10372 by 16·732.

```
     62·10372
       16·732
     --------
     12420744
    18631116
   43472604
  37262232
  6210372
-------------
1039·11944304 = the product required.
```

Observe that the number of figures in the product from the right hand, accounted as decimals, are equal to the number of decimals in the multiplier and multiplicand taken together.

Ex. 4. Divide 39·375 by 9·25.

$$
\begin{array}{l}
9{\cdot}25)39{\cdot}375(4{\cdot}256 = \text{the quotient required.} \\
\quad\;\; 3700 \\
\quad\;\; \overline{\;\;2375} \\
\quad\;\;\;\; 1850 \\
\quad\;\;\;\; \overline{\;\;5250} \\
\quad\;\;\;\;\;\; 4625 \\
\quad\;\;\;\;\;\; \overline{\;\;6250} \\
\quad\;\;\;\;\;\;\;\; 5550 \\
\quad\;\;\;\;\;\;\;\; \overline{\;\;\;700} \\
\end{array}
$$

Observe that the number of decimals in the divisor and quotient together, must be equal to the number in the dividend.

Note.—The operation might be still continued, so as to reduce the quotient to a degree of greater exactitude, but in practice it is quite unnecessary, being even now reduced to a measure of greater nicety than is commonly required.

Definitions of Arithmetical signs employed in the following calculations, which ought to be particularly attended to.

$=$	sign of	equality, and	signifies	equal to, as 3 added $4 = 7$.
$+$	„	addition	„	plus or more, as $5 + 3 = 8$.
$-$	„	subtraction	„	minus or less, as $8 - 3 = 5$.
$\times$	„	multiplication	„	multiplied by, as $8 \times 3 = 24$.
$\div$	„	division	„	divided by, $24 \div 4 = 6$ or $\frac{24}{4} = 6$.
: : : :		proportion	„	that 2 is to 3 as 4 is to 6, &c.
$\sqrt{\;}$	„	square root	„	evolution, or the extr^{n}. of roots;
$\sqrt[3]{\;}$	„	cube root	„	thus, $\sqrt{64} = 8$ and $\sqrt[3]{64} = 4$.
4^2	„	to be squared	„	involution, or the raising of powers;
4^3	„	to be cubed	„	thus, $4^2 = 16$, and $4^3 = 64$.

$\overline{3 + 5} \times 4 = 32$ that, 3 plus 5, or 8 multiplied by $4 = 32$.

$\sqrt{5^2 - 3^2} = 4$ 5 squared, minus 3 squared, the square root of the remainder $= 4$.

$\sqrt[3]{\dfrac{20 \times 12}{30}} = 2$, 20 multiplied by 12, and divided by 30, the cube root of the quotient $= 2$.

BRITISH STANDARD MEASURES.

1. *Measures of length.*

12 inches	=1 foot.
3 feet	=1 yard.
5½ yards	=1 pole or rod.
40 poles	=1 furlong.
8 furlongs, 1760 yards, or 5280 feet .	=1 mile.

2. *Measures of surface, or square measure.*

144 square inches	=1 square foot.
9 square feet	=1 square yard.
30¼ square yards	=1 square pole.
40 square poles	=1 rood.
4 roods, or 4840 square yards . .	=1 acre.

3. *Measures of solidity, or cubic measure.*

1728 cubic inches	=1 cubic foot.
27 cubic feet	=1 cubic yard.

4. *Measures of capacity.*

LIQUIDS.

8·665 cubic inches	=1 gill.
4 gills	=1 pint.
2 pints	=1 quart.
4 quarts, or 277¼ cubic inches . .	=1 gallon.

GRAIN, FRUITS, &c.

2 gallons	=1 peck.
4 pecks, or 2218·192 cubic inches .	=1 bushel.
8 bushels	=1 quarter.
5 quarters	=1 load.

5. *Measures of weight.*

TROY.

24 grains	=1 pennyweight.
20 pennyweights	=1 ounce.
12 ounces	=1 pound.

AVOIRDUPOIS.

27·34375 troy grains	=1 dram.
16 drams	=1 ounce.
16 ounces	=1 pound.
14 pounds	=1 stone.
2 stones	=1 quarter.
4 quarters, or 112 lbs.	=1 cwt.
20 cwt.	=1 ton.

BRITISH SPECIAL MEASURES.

1. *Lineal measures for land.*

7·92 inches	= 1 link.
100 links or 22 yards	= 1 chain.
80 chains	= 1 mile.
69·121 miles	= 1 geog. degree.

2. *Square measures for land.*

62·7264 square inches	= 1 square link.
10,000 square links	= 1 square chain.
10 square chains	= 1 acre.

3. *Nautical measures.*

6082·66 feet	= 1 nautical mile.
3 miles	= 1 league.
20 leagues	= 1 degree.
360 degrees	= the earth's circumference.

Miscellaneous special measures.

6 lineal feet	= 1 fathom.	
100 square feet	= 1 square of flooring.	
272 sq. feet, at 14 in. in thickness	= 1 rod of brick-work.	
600 square feet of inch boards	= 1 load.	
40 cubic feet of round timber 50 cubic feet of hewn timber	= 1 ton or load.	
40 cubic feet	= 1 ton of shipping.	
120 deals	= 1 hundred.	
120 nails	= 1 hundred.	
1200 do.	= 1 thousand.	
500 bricks	= 1 load.	
32 bushels of lime	= 1 do.	
36 do. sand	= 1 do.	
19½ cwt.	= 1 fother of lead.	
108 cubic feet	= 1 stack of wood.	
42 gallons	= 1 tierce.	old wine measure.
63 do.	= 1 hogshead	
84 do.	= 1 puncheon	
126 do.	= 1 pipe	
252 do.	= 1 tun	
36 do.	= 1 barrel	old ale measure.
54 do.	= 1 hogshead	
72 do.	= 1 puncheon	
108 do.	= 1 butt	

DECIMAL APPROXIMATIONS FOR FACILIT CALCULATIONS IN MENSURATION.

Lineal feet multiplied by		·00019	= miles.
„ yards	„	·000568	= „
Square inches	„	·007	= square feet.
„ yards	„	·0002067	= acres.
Circular inches	„	·00546	= square feet.
Cylindrical inches	„	·0004546	= cubic feet.
„ feet	„	·02909	= cubic yards.
Cubic inches	„	·00058	= cubic feet.
„ feet	„	·03704	= cubic yards.
„ „	„	6·232	= imperial gall
„ inches	„	·003607	= „ „
Cylindrical feet	„	4·895	= „ „
„ inches	„	·002832	= „ „
Cubic inches	„	·263	= lbs. av^s. of c
„ „	„	·281	= „ wroug
„ „	„	·283	= „ steel.
„ „	„	·3225	= „ copper
„ „	„	·3037	= „ brass.
„ „	„	·26	= „ zinc.
„ „	„	·4103	= „ lead.
„ „	„	·2636	= „ tin.
„ „	„	·4908	= „ mercu
Cylindrical inches	„	·2065	= „ cast ir
„	„	·2168	= „ wroug
„	„	·2223	= „ steel.
„	„	·2533	= „ copper
„	„	·2385	= „ brass.
„	„	·2042	= „ zinc.
„	„	·3223	= „ lead.
„	„	·207	= „ tin.
„	„	·3854	= „ mercu
Avoirdupois lbs.	„	·009	= cwts.
„	„	·00045	= tons.

DECIMAL EQUIVALENTS TO FRACTIONAL PARTS OF LINEAL MEASURES.

One inch, the integer or whole number. (are equal to)

·96875	7/8 & 3/32	·625	5/8	·28125	1/4 & 1/32
·9375	7/8 & 1/16	·59375	1/2 & 3/32	·25	1/4
·90625	7/8 & 1/32	·5625	1/2 & 1/16	·21875	1/8 & 3/32
·875	7/8	·53125	1/2 & 1/32	·1875	1/8 & 1/16
·84375	3/4 & 3/32	·5	1/2	·15625	1/8 & 1/32
·8125	3/4 & 1/16	·46875	3/8 & 3/32	·125	1/8
·78125	3/4 & 1/32	·4375	3/8 & 1/16	·09375	3/32
·75	3/4	·40625	3/8 & 1/32	·0625	1/16
·71875	5/8 & 3/32	·375	3/8	·03125	1/32
·6875	5/8 & 1/16	·34375	1/4 & 3/32		
·65625	5/8 & 1/32	·3125	1/4 & 1/16		

One foot, or 12 inches, the integer. (are equal to)

·9166	11 inches.	·4166	5 in.	·0625	3/4 of in.
·6338	10 "	·3333	4 "	·05208	5/8 "
·75	9 "	·25	3 "	·04166	1/2 "
·6666	8 "	·1666	2 "	·03125	3/8 "
·5833	7 "	·0833	1 "	·02083	1/4 "
·5	6 "	·07291	7/8 "	·01041	1/8 "

One yard, or 36 inches, the integer. (are equal to)

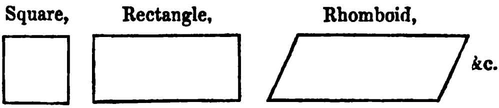
·9722	35 inches.	·6389	23 inches.	·3055	11 inches.
·9444	34 "	·6111	22 "	·2778	10 "
·9167	33 "	·5833	21 "	·25	9 "
·8889	32 "	·5556	20 "	·2222	8 "
·8611	31 "	·5278	19 "	·1944	7 "
·8333	30 "	·5	18 "	·1667	6 "
·8056	29 "	·4722	17 "	·1389	5 "
·7778	28 "	·4444	16 "	·1111	4 "
·75	27 "	·4167	15 "	·0833	3 "
·7222	26 "	·3889	14 "	·0555	2 "
·6944	25 "	·3611	13 "	·0278	1 "
·6667	24 "	·3333	12 "		

MENSURATION.

MENSURATION is that branch of Mathematics which is employed in ascertaining the extension, solidities, and capacities of bodies, capable of being measured.

1. MENSURATION OF SURFACE.

To measure or ascertain the quantity of surface in any right-lined figure whose opposite sides are parallel to each other, as a



Rule.—Multiply the length by the breadth; the product is the area or superficial contents.

Application of the rule to practical purposes.

1. The side of a square piece of board is $8\frac{3}{16}$ inches in length; required the area or superficies.

Decimal equivalent to the fraction $\frac{3}{16} = \cdot1875$ (see page 31); and $8\cdot1875 \times 8\cdot1875 = 67\cdot03515625$ square inches, the area.

2. The length of the fire-grate under the boiler of a steam engine is 4 feet 7 inches, and its width 3 feet 6 inches; required the area of the fire-grate.

7 in. $= \cdot5833$ and 6 in. $= \cdot5$ (see Table of Equivalents, p. 31): hence $4\cdot5833 \times 3\cdot5 = 16\cdot04155$ square feet, the area.

3. Required the number of square yards in a floor whose length is $13\frac{1}{2}$, and breadth $9\frac{3}{4}$ feet.

$$13\cdot5 \times 9\cdot75 = 131\cdot625 \div 9 = 14\cdot625 \text{ square yards.}$$

Note 1.—The above rule is rendered equally applicable to figures whose sides are not parallel to each other, by taking the mean breadth as that by which the contents are to be estimated.

2. The square root of any given sum equals the side of a square of equal area.

3. Any square whose side is equal to the diagonal of another square, contains double the area of that square.

4. Any sum or area (of which to form a rectangle) divided by the breadth, the quotient equals the length; or divided by the length, the quotient equals the breadth of the rectangle required.

TRIANGLES.

Any two sides of a right-angled triangle being given, to find the third side.

Rule 1.—Add together the squares of the base and perpendicular, and the square root of the sum is the hypotenuse or longest side.

Rule 2.—Add together the hypotenuse and any one side, multiply the sum by their difference, and the square root of the product equals the other side.

Application to practical purposes.

1. Wanting to prop a building with raking shores, the top ends of which to be 25 feet from the ground, and the bottom ends, 16 feet from the base of the building; what must be their length, independent of any extra length allowed below the surface of the ground?

$\overline{25^2 + 16^2} = \sqrt{881} = 29\cdot6816$ feet, or $\cdot6816 \times 12 = 8$ inches; consequently, 29 feet 8 inches nearly.

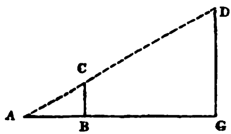
2. From the top of a wall 18 feet in height, a line was stretched across a canal for the purpose of ascer-

taining its breadth; the length of the line, when measured, was found to be 40 feet; required the breadth from the opposite embankment to the base of the wall.

$40-18=22$, and $\sqrt{\overline{40+18}\times 22}=\sqrt{1276}=35{\cdot}72$, or 35 feet 9 inches nearly, the width of the canal.

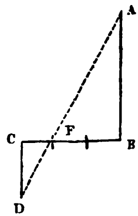
Triangles similar to each other are proportional to each other; hence their utility in ascertaining the heights and distances of inaccessible objects.

Thus, suppose the height of an inaccessible object D is required, I find by means of two staffs or otherwise, the height of the perpendicular B C and the length of the base line A B; also the distance from A to the base of the object G D;



then A B : B C : : A G : G D. And suppose A B = 6 feet, B C = 2 feet, and A G = 150;
6 : 2 : : 150 : 50 feet, the height of D from G.

Again, suppose the inaccessible distance A be required, make the line B A, B C, at right angles, and B C of three or four equal parts of any convenient distance, through one of which and in a line with the object A, determine the triangle C D F, then the proportion will be as

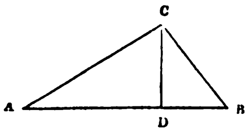


C F : C D : : B F : B A. Let C F = 10 yards, C D = 53, and B F = 30, 10 : 53 : : 30 : 159 yards, the distance from B.

To find the area of a triangle when the base and perpendicular are given.

Rule.—Multiply the base by the perpendicular height, and half the product is the area.

1. The base of the triangle A D B is $11\frac{3}{32}$ inches in length, and the height D C, $3\frac{3}{8}$ inches; required the area.



$\frac{3}{32}=\cdot09375$ and $\frac{3}{8}=\cdot375$ (see page 31):

hence $\frac{11\cdot09375\times3\cdot375}{2}=18\cdot72075$ square inches, the area.

2. The base of a triangle is 53 feet 3 inches, and the perpendicular 7 feet 9 inches; required the area or superficies.

$$\frac{53\cdot25\times7\cdot75}{2}=206\cdot34375 \text{ square feet, the area.}$$

When only the three sides of a triangle can be given, to find the area.

Rule.—From half the sum of the three sides, subtract each side severally; multiply the half sum and the three remainders together, and the square root of the product is equal to the area required.

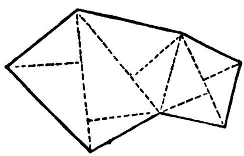
Required the area of a triangle whose three sides are respectively 50, 40, and 30 feet.

$\frac{50+40+30}{2}=60$, or half the sum of the three sides.

$60-30=30$, first difference,
$60-40=20$, second difference,
$60-50=10$, third difference;

then $30\times20\times10\times60=\sqrt{360000}=600$, the area required.

Triangles are employed to great advantage in determining the area of any rectilineal figure, as the annexed, and by which the measurement is rendered comparatively simple.



POLYGONS.

Polygons being composed of triangles, may of course be similarly measured: hence in regular polygons, multiply the length of a side by the perpendicular height to the centre, and by the number of sides, and half the product is the area.

Table relative to the Construction and Estimation of Polygons.

Name.	No. of sides.	Angle at centre.	Angle at circum.	Perpen. side being 1.	Length of side, radius being 1.	Radius of circle, side being 1.	Radius of circle, per. being 1.	Area, side being 1.
Triangle .	3	120°	60°	0·2886	1·73	·579	2	0·4330
Square . . .	4	90	90	0·5	1·412	·705	1·41	1
Pentagon .	5	72	108	0·6882	1·174	·852	1·238	1·7204
Hexagon .	6	60	120	0·8660	1	1	1·156	2·5980
Heptagon .	7	$51\frac{3}{7}$	$128\frac{4}{7}$	1·0382	·867	1·16	1·11	3·6339
Octagon .	8	45	135	1·2071	·765	1·307	1·08	4·8284
Nonagon .	9	40	140	1·3737	·681	1·47	1·062	6·1818
Decagon .	10	36	144	1·5388	·616	1·625	1·05	7·6942
Undecagon	11	$32\frac{8}{11}$	$147\frac{3}{11}$	1·7028	·561	1·777	1·04	9·3656
Dodecagon	12	30	150	1·8660	·516	1·94	1·037	11·1961

Application of the Table.

1. The radius of a circle being $6\frac{1}{2}$ feet, required the side of the greatest heptagon that may be inscribed therein.

$\cdot 867 \times 6\cdot 5 = 5\cdot 6355$, or 5 feet $7\frac{1}{2}$ inches nearly.

2. Each side of a pentagon is required to be 9 feet; required the radius of circumscribing circle.

$\cdot 852 \times 9 = 7\cdot 668$, or 7 feet 8 inches.

3. A perpendicular from the centre to either side of an octagon is required to be 12 feet; what must be the radius of circumscribing circle?

$1\cdot 08 \times 12 = 12\cdot 96$, or 12 feet $11\frac{1}{2}$ inches.

4. Each side of a hexagon is $4\frac{1}{2}$ yards; required its superficial contents.

$4\frac{1}{2}^2 \times 2\cdot 598 = 52\cdot 6095$ square yards.

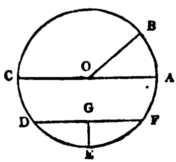
THE CIRCLE AND ITS SECTIONS.

Observations and definitions.

1. The circle contains a greater area than any other plane figure bounded by the same perimeter or outline.

2. The areas of circles are to each other as the squares of their diameters; any circle twice the diameter of another contains four times the area of the other.

3. The radius of a circle is a straight line drawn from the centre to the circumference, as O B.



4. The diameter of a circle is a straight line drawn through the centre, and terminated both ways at the circumference, as C O A.

5. A chord is a straight line joining any two points of the circumference, as D F.

6. The versed sine is a straight line joining the chord and circumference, as E G.

7. An arc is any part of the circumference, as C D E.

8. A semicircle is half the circumference cut off by a diameter, as C E A.

9. A segment is any portion of a circle cut off by a chord, as D E F.

10. A sector is a part of a circle cut off by two radii, as A O B.

General rules in relation to the circle.

1. Multiply the diameter by 3·1416, the product is the circumference.

2. Multiply the circumference by ·31831, the product is the diameter.

3. Multiply the square of the diameter by ·7854, the product is the area.

4. Multiply the square root of the area by 1·12837, the product is the diameter.

5. Multiply the diameter by ·8862, the product is the side of a square of equal area.

6. Multiply the side of a square by 1·128, the product is the diameter of a circle of equal area.

Application of the rules as to purposes of practice.

1. The diameter of a circle being $7\frac{3}{16}$ inches, required its circumference.

$7{\cdot}1875 \times 3{\cdot}1416 = 22{\cdot}58025$ inches, the circumference.

Or, the diameter being $30\frac{1}{2}$ feet, required the circumference.

$3{\cdot}1416 \times 30{\cdot}5 = 95{\cdot}8188$ feet the circumference.

2. A straight line or the circumference of a circle

being 274·89 inches, required the circle's diameter corresponding thereto.

$274{\cdot}89 \times {\cdot}31831 = 87{\cdot}5$ inches diameter.

Or, what is the diameter of a circle when the circumference is 39 feet?

${\cdot}31831 \times 39 = 12{\cdot}41409$ feet, and ${\cdot}41409 \times 12 = 4{\cdot}96908$ inches, or 12 feet 5 inches, very nearly the diameter.

3. The diameter of a circle is 3¾ inches; what is its area in square inches?

$3{\cdot}75^2 = 14{\cdot}0625 \times {\cdot}7854 = 11{\cdot}044$, &c. inches area.

Or, suppose the diameter of a circle 25 feet 6 inches, required the area.

$25{\cdot}5^2 = 650{\cdot}25 \times {\cdot}7854 = 510{\cdot}706$, &c. feet, the area.

4. What must the diameter of a circle be, to contain an area equal to 706·86 square inches?

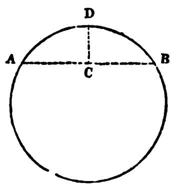
$\sqrt{706{\cdot}86} = 26{\cdot}586 \times 1{\cdot}12837 = 29{\cdot}998$ or 30 inches, the diameter required.

5. The diameter of a circle is 14¼ inches; what must I make each side of a square, to be equal in area to the given circle?

$14{\cdot}25 \times {\cdot}8862 = 12{\cdot}62835$ inches, length of side required.

Any chord and versed sine of a circle being given, to find the diameter.

Rule.—Divide the sum of the squares of the chord and versed sine by the versed sine; the quotient is the diameter of corresponding circle.



1. The chord of a circle A B equal 6½ feet, and the versed sine C D equal 2 feet; required the circle's diameter.

$\overline{6{\cdot}5^2 + 2^2} = 46{\cdot}25 \div 2 = 23{\cdot}125$ feet, the diameter.

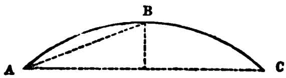
2. In a curve of a railway, I stretched a line 72 feet in length, and the distance from the line to the curve I found to be $1\frac{1}{4}$ ft.; required the radius of the curve.

$$\overline{72^2 + 1{\cdot}25^2} = 5185{\cdot}5625, \text{ and } \frac{5185{\cdot}5625}{1{\cdot}25 \times 2} = 2074{\cdot}225 \text{ ft. the radius.}$$

To find the length of any given arc of a circle.

Rule.—From eight times the chord of half the arc, subtract the chord of the whole arc, and one-third of the remainder is equal the length of the arc.

Required the length of the arc A B C, the chord A B of half the arc being 4 feet 3 inches, and chord A C of the whole arc 8 feet 4 inches.



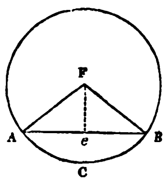
$$4{\cdot}25 \times 8 = 34, \text{ and } 34 - 8{\cdot}333 = \frac{25{\cdot}667}{3} = 8{\cdot}555 \text{ feet, the}$$

length of the arc.

To find the area of the sector of a circle.

Rule.—Multiply the length of the arc by its radius, and half the product is the area.

The length of the arc A C B equal $9\frac{1}{2}$ feet, and the radii F A, F B, equal each 7 feet; required the area.



$9{\cdot}5 \times 7 = 65{\cdot}5 \div 2 = 32{\cdot}75$, the area.

Note.—The most simple means whereby to find the area of the segment of a circle, is, to first find the area of a sector whose arc is equal to that of the given segment; and if it be less than a semicircle, subtract the area of the triangle formed by the chord of the segment and radii of its extremities; but if more than a semicircle, add the area of the triangle to the area of the sector, and the remainder or sum is the area of the segment.

Thus, suppose the area of the segment A C B *e* is required, and that the length of the arc A C B equal 9¾ feet, F A and F B each equal 7 feet, and the chord A B equal 8 feet 4 inches, also the perpendicular *e* F equal 3¾ feet.

$$\frac{9{\cdot}75 \times 7}{2} = 34{\cdot}125 \text{ feet, the area of the sector.}$$

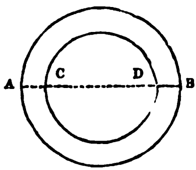
$$\frac{8{\cdot}333 \times 3{\cdot}75}{2} = 15{\cdot}624 \text{ feet, area of the triangle.}$$

And $34{\cdot}125 - 15{\cdot}624 = 18{\cdot}501$ feet, the area of the segment.

To find the area of the space contained between two concentric circles.

Rule.—Multiply the sum of the inside and outside diameters by their difference, and by ·7854; the product is the area.

1. Suppose the external circle A B equal 32 inches, and internal circle C D equal 28 inches; required the area of the space contained between them.



$\overline{32 + 28} = 60$, and $32 - 28 = 4$; hence $60 \times 4 \times {\cdot}7854 = 188{\cdot}496$ in. the area.

2. The exterior diameter of the fly-wheel of a steam engine is 20 feet, and the interior diameter 18½ feet; required the area of the surface or rim of the wheel.

$\overline{20 + 18{\cdot}5} = 38{\cdot}5$, and $20 - 18{\cdot}5 = 1{\cdot}5$; hence $38{\cdot}5 \times 1{\cdot}5 \times {\cdot}7854 = 45{\cdot}35$, &c. feet, the area.

To find the area of an ellipse or oval.

Rule.—Multiply the longest diameter by the shortest, and the product by ·7854; the result is the area.

An oval is 25 inches by 16·5; what are its superficial contents?

$$25 \times 16{\cdot}5 = 412{\cdot}5 \times {\cdot}7854 = 323{\cdot}9775 \text{ inches, the area.}$$

Note.—Multiply half the sum of the two diameters by 3·1416, and the product is the circumference of the oval or ellipse.

To find the area of a parabola, or its segment.

Rule.—Multiply the base by the perpendicular height, and two-thirds of the product is the area.

What is the area of a parabola whose base is 20 feet and height 12?

$$20 \times 12 = \frac{240 \times 2}{3} = 160 \text{ feet, the area.}$$

Note.—Although the whole of the preceding practical applications or examples are given in measures of feet or inches, these being considered as the most generally familiar, yet the rules are equally applicable to any other unit of measurement whatever, as yards, chains, acres, &c., &c., &c.

2. MENSURATION OF THE SUPERFICIES, SOLIDITIES, AND CAPACITIES OF BODIES.

To find the solidity or capacity of any figure in the cubical form.

Rule.—Multiply the length of any one side by its breadth and by the depth or distance to its opposite side; the product is the solidity or capacity, in equal terms of measurement.

Application of the rule to practical purposes.

1. Required the number of cubic inches in a piece of timber $23\frac{1}{2}$ inches long, $7\frac{3}{4}$ inches broad, and $3\frac{5}{8}$ inches in thickness.

$$23{\cdot}5 \times 7{\cdot}75 \times 3{\cdot}625 = 660{\cdot}203 \text{ cubic inches.}$$

2. A rectangular cistern is in length $8\frac{1}{3}$ feet, in breadth $5\frac{1}{4}$ feet, and in depth 4 feet; required its

capacity in cubic feet, also its capacity in British imperial gallons.

$8{\cdot}5 \times 5{\cdot}25 \times 4 = 178{\cdot}5$ cubic feet, and $178{\cdot}5 \times 6{\cdot}232$ (see Table of Decimal Approximations, p. 30) $= 1112{\cdot}412$ gallons.

3. A rectangular cistern capable of containing 520 imperial gallons is to be $7\frac{1}{4}$ feet in length, and $4\frac{1}{2}$ feet in width; it is required to ascertain the necessary depth.

$7{\cdot}25 \times 4{\cdot}5 \times 6{\cdot}232 = 203{\cdot}318$, and $\dfrac{520{\cdot}000}{203{\cdot}318} = 2{\cdot}557$ feet, or 2 feet $6\frac{3}{4}$ inches nearly.

4. A rectangular piece of cast iron, 20 inches long and 6 inches broad, is to be formed of sufficient dimensions to weigh 150 lbs.; what will be the depth required?

$20 \times 6 \times {\cdot}263$ (see Table of Decimal Approximations, Cast Iron, p. 30) $= 31{\cdot}96$, and $\dfrac{150}{31{\cdot}96} = 4{\cdot}69$ in., or 4 and $\frac{11}{16}$ in., the thickness required.

To find the convex surface, and solidity or capacity, of a cylinder.

Rule 1.— Multiply the circumference of the cylinder by its length or height; the product is the convex surface.

Rule 2.—Multiply the area of the diameter by the length or height, and the product is the cylinder's solidity or capacity, as may be required.

Application of the rules.

1. The circumference of a cylinder is $37\frac{1}{2}$ inches, and its length $54\frac{3}{4}$ inches; required the convex surface in square feet.

$54{\cdot}75 \times 37{\cdot}5 \times {\cdot}007$ (see Table of Approximations) $= 14{\cdot}371$ square feet.

2. A cylindrical piece of timber is 9 inches dia-

meter, and 3 feet 4 inches in length; required its solidity in cubic inches, and also in cubic feet.

3 feet 4 inches = 40 inches, and $9^2 \times \cdot 7854 \times 40 = 2544\cdot 696$ cubic inches; then $2544\cdot 696 \times \cdot 00058 = 1\cdot 4759$ cubic feet.

3. Suppose a well to be 4 feet 9 inches diameter, and 16½ feet from the bottom to the surface of the water; how many imperial gallons are therein contained?

$$4\cdot 75^2 \times 16\cdot 5 \times 4\cdot 895 = 1822\cdot 162 \text{ gallons.}$$

4. Again, suppose the well's diameter the same, and its entire depth 35 feet; required the quantity in cubic yards of material excavated in its formation.

$$4\cdot 75^2 \times 35 \times \cdot 02909 = 22\cdot 973 \text{ cubic yards.}$$

5. I have a cylindrical cistern capable of holding 7068 gallons, and its depth is 10 feet; now I want to replace it with one of an equal depth, but capable of holding 12,500 gallons; what must be its diameter?

$4\cdot 895 \times 10 = 48\cdot 95$, and $\frac{12500}{48\cdot 95} = \sqrt{255\cdot 3} = 15\cdot 9687$ feet, or 15 feet 11⅝ inches.

6. A cylindrical piece of lead is required 7½ inches diameter, and 168 lbs. in weight; what must be its length in inches?

$$7\cdot 5^2 \times \cdot 3223 = 18, \text{ and } \frac{168}{18} = 9\cdot 3 \text{ inches.}$$

To find the length of a cylindrical helix, or spiral, wound round a cylinder.

Rule.—Multiply the circumference of the base by the number of revolutions of the spiral, and to the square of the product add the square of the height; the square root of the sum is the length of the spiral.

Application of the rule.

1. Required the length of the thread or screw twisting round a cylinder 22 inches in circumference $3\frac{1}{2}$ times, and extending along the axis 16 inches.

$22 \times 3{\cdot}5 = 77^2 = 5929$, and $16^2 = 256$; then $\sqrt{5929 + 256} = 78{\cdot}64$ inches.

2. The well of a winding staircase is 5 feet diameter, and height to the top landing 25 feet, the hand-rail is to make $2\frac{1}{2}$ revolutions; required its length.

5 feet diameter $= 15{\cdot}7$ feet circumference.
$15{\cdot}7 \times 2{\cdot}5 = 39{\cdot}25^2 = 1540{\cdot}5625$, and $25^2 = 625$; then
$\sqrt{1540 + 625} = 46{\cdot}5$ feet, the length required.

To find the convex surface, solidity, or capacity of a cone or pyramid.

Rule 1.—Multiply the circumference of the base by the slant height, and half the product is the slant surface.

Rule 2.—Multiply the area of the base by the perpendicular height, and one-third of the product is the solidity or capacity, as may be required.

Application of the rules.

1. Required the area in square inches of the slant surface of a cone whose slant height equals $18\frac{3}{4}$ inches, and diameter at the base $6\frac{1}{4}$ inches.

$6{\cdot}25 \times {\cdot}3{\cdot}1416 = 19{\cdot}635$, circumference of the base; and

$$\frac{19{\cdot}635 \times 18{\cdot}75}{2} = 184{\cdot}078125 \text{ square inches.}$$

2. Required the quantity of lead, in square feet, sufficient to cover the slant surface of a hexagonal pyramid whose slant height is 42 feet, and the breadth of each side at the base 4 feet 9 inches.

$$\frac{4{\cdot}75 \times 42 \times 6 \text{ sides}}{2} = 598{\cdot}5 \text{ square feet.}$$

3. What is the solidity of a cone in cubic inches, the diameter at the base being 15 inches, and perpendicular height $32\frac{1}{2}$ inches?

$$\frac{15^2 \times \cdot7854 \times 32\cdot5}{3} = 1914\cdot4125 \text{ cubic inches.}$$

4. In a square solid pyramid of stone 67 feet in height, and $16\frac{1}{2}$ feet at the base, how many cubic feet?

$$\frac{16\cdot5 \times 16\cdot5 \times 67}{3} = 6080\cdot25 \text{ cubic feet.}$$

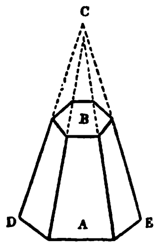
To find the solidity or capacity of any frustum of a cone or pyramid.

Rule.—If the base be a circle, add into one sum the two diameters, or, if a regular polygon, the breadth of one side at the top and at the base; then from the square of the sum subtract the product of these diameters or breadths; multiply the remainder by ·7854, if a circle, or by the tabular area (see Table of Polygons, p. 36) and by one-third of the height, and the product is the content in equal terms of unity.

Note.—Where the whole height of the cone or pyramid can be obtained, of which the given frustum forms a part, the most simple method is first to find the whole contents, then the contents extending beyond the frustum, and subtracting the less from the greater, leaves the contents of the frustum required.

Application of the rules.

1. The perpendicular height A B of the frustum of a hexagonal pyramid C D E, is $7\frac{1}{2}$ feet, and the breadth of each side at top and base equal $3\frac{3}{4}$ and $2\frac{1}{2}$ feet; required the solid contents of the frustum in cubic feet.

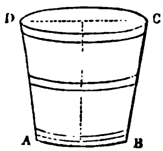


$\cdot 75 + 2{\cdot}5 = 6{\cdot}25$, and $6{\cdot}25 \times 6{\cdot}25 = 39{\cdot}0625$; then $3{\cdot}75 \times 2{\cdot}5 = 9{\cdot}375$, and $39{\cdot}0625 - 9{\cdot}375 = 29{\cdot}6875 \times 2{\cdot}598$ (tabular area, p. 36) $= 77{\cdot}138 \times 2{\cdot}5$ or $\frac{1}{3}$ of the height $= 192{\cdot}845$ cubic feet.

2. Required the solidity of the frustum of a cone, he top diameter of which is 7 inches, the base dia- ieter $9\frac{1}{2}$, and the perpendicular height 12.

$\overline{+ 9{\cdot}5^2} = 272{\cdot}25$, and $7 \times 9{\cdot}5 = 66{\cdot}5$; then $272{\cdot}25 - 66{\cdot}5 = 205{\cdot}75 \times {\cdot}7854 = 161{\cdot}576 \times 4$ or $\frac{1}{3}$ of the height $= 646{\cdot}3$ cubic inches.

3. A vessel in the form of an in- erted cone, as A B C D, is 5 feet in iameter at the top, 4 feet at the ottom, and 6 feet in depth; re- uired its capacity in imperial gal- ons.



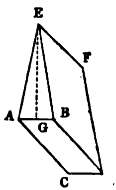
$\overline{+ 4} = 9^2 = 81$, and $5 \times 4 = 20$; hence $81 - 20 = 61 \times {\cdot}7854$, and by 2 or $\frac{1}{3}$ of the depth $= 95{\cdot}8188$ cubic feet, and $\times 6{\cdot}232 = 597{\cdot}1427$ gallons.

To find the solid contents of a wedge.

Rule.—To twice the length of the base add the ength of the edge; multiply the sum by the breadth f the base, and by the perpendicular height from he base, and one-sixth of the product is the solid ontents.

Application of the rule.

Required the solidity of a wedge in ubic inches, the base A B C D being inches by $3\frac{1}{2}$, the edge E F, 7 inches, nd the perpendicular height G E, 15.



$$\frac{\overline{18 + 7} \times 3{\cdot}5 \times 15}{6} = 218{\cdot}75 \text{ cubic inches.}$$

To find the convex surface, the solidity, or the capacity of a sphere or globe.

Rule 1.—Multiply the square of the diameter by 3·1416, the product is the convex surface.

Rule 2.—Multiply the cube of the diameter by ·5236, the product is the solid contents.

Rule 3.—Multiply the cube of the diameter in feet by 3·263, or in inches by ·001888, the product is the capacity in imperial gallons.

Application of the rules.

1. Required the convex surface, the solidity, and the weight in cast iron, of a sphere or ball $10\frac{1}{2}$ inches in diameter.

$10{\cdot}5^2 \times 3{\cdot}1416 = 346{\cdot}3614$ square inches.
$10{\cdot}5^3 \times {\cdot}5236 = 606{\cdot}132$, &c. cubic inches; and
$606{\cdot}132 \times {\cdot}263$ (see Table of Approximations, p. 30) $= 159{\cdot}4$ lbs.

2. A hollow or concave copper ball is required 8 inches diameter, and in weight just sufficient to sink to its centre in common water; what is the proper thickness of copper of which it must be made?

Weight of a cubic inch of water $= {\cdot}03617$ lbs. } see p. 113.
" " copper $= {\cdot}3225$ " }

$$\frac{8^3 \times {\cdot}5236 \times {\cdot}03617}{2} = 4{\cdot}84828 \text{ cub. in. of water to be displaced.}$$

$$\text{And } \frac{4{\cdot}84828}{{\cdot}3225} = 15{\cdot}0334 \text{ cubic inches of copper in the ball.}$$

Then $8^2 \times 3{\cdot}1416 = 201{\cdot}0624$, and $\frac{15{\cdot}0334}{201{\cdot}0624} = {\cdot}0747$ inch, the thickness of copper required.

${\cdot}0747 \times 16 = \frac{1}{16}$ of an inch full, or 3 lbs. copper to a square foot.

3. What diameter must I make a leaden ball, so as to weigh 72 lbs.?

${\cdot}5236 \times {\cdot}4103 = {\cdot}21483308$, and $\frac{72}{{\cdot}21483308} = \sqrt[3]{340} = 6{\cdot}97$ inches diameter.

To ascertain the amount of convex surface, also the solid contents, of the segment of a globe.

Rule 1.—Multiply the circumference of the globe or sphere by the height of the segment, and the product is the convex surface.

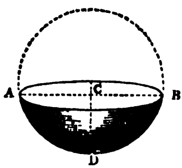
Rule 2.—To three times the square of the segment's radius add the square of its height, multiply the sum by the height, and by ·5236; the product is the solid contents.

Application of the Rules.

1. Required the number of square feet in the convex surface of a sphere, the height of which is $9\frac{1}{2}$ feet, and the circumference of the sphere of which it is a part equal $70\frac{1}{2}$ feet.

$$70{\cdot}5 \times 9{\cdot}5 = 669{\cdot}75 \text{ square feet.}$$

2. The radius A C or B C of the spherical segment A D B equal 48 inches, and the height D C equal 12 inches; required its solidity in cubic inches.



$48^2 \times 3 = 6912$, and $12^2 = 144$; then

$\overline{6912 + 144} \times 12 \times {\cdot}5236 = 44334{\cdot}75$ cubic inches.

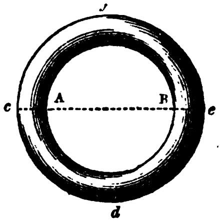
To find the convex surface and solidity of a cylindrical ring.

Rule 1.—To the sectional diameter of the ring add the inner diameter of the circle, multiply the sum by the sectional diameter, and by 9·8696; the product is the convex surface.

Rule 2.—To the sectional diameter of the ring add the inner diameter of the circle, multiply the sum by the square of the sectional diameter, and by 2·4674; the product is the solid contents.

Application of the Rules.

The inner diameter A B of the cylindric ring *c d e f* equal 18 feet, and the sectional diameter *c* A or B *e* equal 9 inches; required the convex surface and solidity of the ring.



18 feet × 12 = 216 inches, and

$\overline{216+9} \times 9 \times 9{\cdot}8696 = 19985{\cdot}94$ square inches.

$\overline{216+9} \times 9^2 \times 2{\cdot}4674 = 44968{\cdot}365$ cubic inches.

In the formation of a hoop or ring of wrought iron, it is found in practice, that in bending the iron the side or edge which forms the interior diameter of the hoop is upset or shortened, while at the same time the exterior diameter is drawn or lengthened; therefore, the proper diameter by which to determine the length of the iron in an unbent state, is the distance from centre to centre of the iron of which the hoop is composed: *hence the rule to determine the length of the iron.* If it is the interior diameter of the hoop that is given, add the thickness of the iron; but if the exterior diameter, subtract from the given diameter the thickness of the iron, multiply the sum or remainder by 3·1416, and the product is the length of the iron, in equal terms of unity.

Supposing the interior diameter of a hoop to be 32 inches, and the thickness of the iron 1¼, what must be the proper length of the iron, independent of any allowance for shutting?

$$\overline{32+1{\cdot}25} = 33{\cdot}25 \times 3{\cdot}1416 = 104{\cdot}458 \text{ inches.}$$

But the same is obtained simply by inspection in the Table of Circumferences.

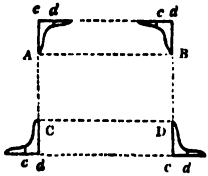
Thus, 33·25 = 2 feet 9¼ in., opposite to which is 8 feet 8½ inches.

Again, let it be required to form a hoop of iron $\frac{7}{8}$ inch in thickness, and 16½ inches outside diameter.

16·5 — ·875 = 15·625, or 1 foot 3⅝ inches;

opposite to which, in the Table of Circumferences, is 4 feet 1 inch, independent of any allowance for shutting.

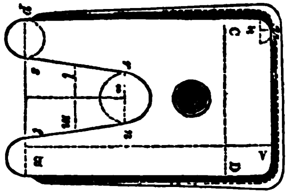
The length for angle iron, of which to form a ring of a given diameter, varies according to the strength of the iron at the root; and the rule is, for a ring with the flange outside, *add* to its required interior diameter, twice the extreme strength of the iron at the root; or, for a ring with the flange inside, *subtract* twice the extreme strength; and the sum or remainder is the diameter by which to determine the length of the angle iron. Thus, suppose two angle iron rings similar to the following be required, the exterior diameter A B, and interior diameter C D, each to be 1 foot 10½ inches, and the extreme strength of the iron at the root *c d*, *c d*, &c. $\frac{7}{8}$ of an inch;



wice $\frac{7}{8}$ = 1¾, and 1 ft. 10½ in. + 1¾ = 2 ft. ¼ in., opposite to which, in the Table of Circumferences, is 6 ft. 4¼ in., the length of the iron for C D; and 1 ft. 10½ in. — 1¾ = 1 ft. 8¾ in., opposite to which is 5 ft. 5¼ in., the length of the iron for A B.

ıt observe as before, that the necessary allowance shutting must be added to the length of the iron, ıddition to the length as expressed by the Table.

Required the capacity in imperial gallons of a Locomotive Engine Tender tank, 2 feet 8 inches in depth, and its superficial dimensions the following, with reference to the annexed plan.



Length, or dist. between	A and B	= 10 ft.	2¾ in.	or,	122·75 in.
Breadth „	C „ D	= 6 „	7½	„	79·5 „
Length „	i „ g	= 3 „	10¾	„	46·75 „
Mean breadth of coke space or	lm „	= 3 „	1¼	„	37·25 „
Diameter of circle	rn	= 2 „	8¼	„	32·25 „
„ „	ps	= 1 „	6½	„	18·5 „
Radius of back corners	vx	=	4	„	4 „

Then, $122·75 \times 79·5 = 9758·525$ square inches, as a rectangle.
And $18·5^2 \times ·7854 = 268·8$ „ „ area of circle formed by the two ends.

Total $10027·325$ „ „ from which deduct the area of the coke space, and the difference of area between the semicircle formed by the two back corners, and that of a rectangle of equal length and breadth;

Then $46·75 \times 37·25 = 1731·4375$ area of r, n, s, t, in sq. ins.
$\dfrac{32·25^2 \times ·7854}{2} = 408·4$ area of half the circle rn.

Radius of back corners = 4 inches;
consequently $8^2 \times ·7854 = 25·13$, the semicircle's area; and $8 \times 4 = 32 - 25·13 = 6·87$ inches taken off by rounding the corners.

Hence, $1731·4375 + 408·4 + 6·87 = 2146·707$, and
$10027·325 - 2146·707 = 7880·618$ square inches, or whole area in plan,
$7880·618 \times 32$ the depth $= 252179·776$ cubic inches, and $252179·776 \times ·003607$ (see Table of Approximations, page 30) $= 909·61245$ gallons.

***Tables combining the Specific Gravities and other Properties of Bodies. Water the standard of comparison, or* 1000.**

METALS.

Names.	Specific gravity.	Melting points in degrees of Fahrenheit.	Contraction in parts of an in. per lineal ft. from the fluid to the average temperature in solid state.	Ultimate cohesive strength of an inch sq. prism in tons.	Scale of wire-drawing ductility.	Scale of laminable ductility.	Ratio of hardness.	Scale as conductors of electricity.	Ratio of power in the conduction of heat.
Platinum	19500	3280	—	—	3	5	—	—	3·8
Pure Gold . . .	19258	2016	—	—	1	1	1·8	3	10·0
Mercury	13500	—	—	—	—	—	—	—	—
Lead	11352	612	·319	·81	8	7	1·0	6	1·8
Pure Silver . . .	10474	1873	—	—	2	2	2·4	2	9·7
Bismuth	9823	476	·156	1·45	—	—	2·0	—	—
Copper, cast . .	8788	1996	·193	8·51	—	—	—	—	—
,, wrought	8910	—	—	15·08	5	3	2·8	1	8·9
Brass, cast . . .	7824	1900	·210	8·01	—	—	to any degree	—	—
,, sheet . .	8396	—	—	12·23	6	6	—	—	8·6
Iron, cast	7264	2786	·125	7·87	—	—	to any degree	—	—
,, bar	7700	—	·137	25·00	4	8	4·7	4	3·7
Steel, soft . . .	7833	—	·133	58·91	—	—	—	—	—
,, hard . . .	7816	—	—	—	—	—	to any degree	—	—
Tin, cast	7291	442	·278	2·11	8	4	1·2	5	3·0
Zinc, cast . . .	7190	773	·329	5·06	7	8	1·6	7	3·6

STONES, EARTHS, &c.

Names.	Specific gravity.	Weight of a cubic foot in lbs.	Cubic feet in a ton.	Tons required to crush $1\frac{1}{2}$-inch cubes.
Marble, average	2720	170·00	13	9·25
Granite, do. . .	2651	165·68	$13\frac{1}{2}$	6·2
Purbeck stone .	2601	162·56	$13\frac{3}{4}$	9·0
Portland do. . .	2570	160·62	14	4·5
Bristol do. . . .	2554	159·62	14	—
Millstone	2484	155·25	$14\frac{1}{4}$	—
Paving stone . .	2415	150·93	$14\frac{3}{4}$	5·7
Craigleith do. .	2362	147·62	15	5·0
Grindstone . . .	2143	133·93	$16\frac{3}{4}$	6·6
Chalk, Brit. . .	2781	173·81	$12\frac{3}{4}$	0·5
Brick	2000	125·00	17	0·8
Coal, Scotch . .	1300	81·15	$27\frac{1}{2}$	—
,, Newcastle	1270	79·37	$27\frac{1}{4}$	—
,, Staffordsh.	1240	77·50	29	—
,, Cannel . .	1238	77·37	29	—

WOODS.							
Names.	Specific gravity, water, 1000.	Average wt. of a cubic foot in lbs.	Cubic feet in a ton.	Ultimate cohesive strength of an inch square prism in lbs.	Comparative Stiffness.	Comparative Strength.	Comparative Resilience.
English oak	934	58	38½	11880	100	100	100
Riga do.	872	54	41½	12888	93	108	125
Dantzic do.	756	47	48	12780	117	107	99
American do.	672	42	53	10253	114	86	64
Beech	852	48	45	12225	77	103	138
Alder	800	46	48½	9540	63	80	101
Plane	640	40	55	10935	78	92	108
Sycamore	604	38	59	9630	59	81	111
Chestnut	610	38	59	10656	67	89	118
Ash	845	52	43	14130	89	119	160
Elm	673	42	53	9720	78	82	86
Mahog. Spanish ..	800	50	45	7560	73	67	61
„ Honduras	637	40	55	11475	93	96	99
Walnut	671	42	53	8800	49	74	111
Teak	750	46	48½	12915	126	109	94
Poona	640	40	55	12350	99	104	82
African oak	944	59	38	17200	101	144	138
Poplar	383	34	66	5928	44	50	57
Cedar	561	33	68	7420	28	62	106
Riga fir	753	47	48	9540	98	80	64
Memel do.	546	34	66	9540	114	80	56
Scotch do.	528	33	68	7110	55	60	65
Christ. wh^{te}. deal .	590	37	60	12346	104	104	104
Am^{n}. white spruce	551	34	66	10296	72	86	102
Yellow pine	461	28	80	11853	95	99	103
Pitch pine	660	41	54½	9796	73	82	92
Larch	530	31	72	12240	79	103	134
Cork	240	15	149	—	—	—	—

LIQUIDS.

Names.	Specific grav., water, 1000.	Weight of an imperial gall. in lbs.
Acid, sulphuric ..	1850	18·5
„ nitric	1271	12·7
„ muriatic ...	1200	12·0
„ fluoric.....	1060	10·6
„ citric......	1034	10·3
„ acetic	1062	10·6
Water from the Baltic	1015	10·2
Water from the Dead Sea	1240	12·4
Water from the Mediterranean .	1029	10·3
Water, distilled ..	1000	10·0
Oils, expressed:		
„ linseed.....	940	9·4
„ sweet almond	932	9·3
„ whale......	923	9·2
„ hempseed...	926	9·3
„ olive.......	915	9·2
Oils, essential:		
„ cinnamon...	1043	10·4
„ lavender....	894	8·9
„ turpentine ..	870	8·7
„ amber......	868	8·7
Alcohol	825	8·2
Ether, nitric	908	9·1
Proof spirit......	922	9·2
Vinegar	1009	10·1

GASES.

Atmospheric air being the standard of comparison, or 1000.

Names.	Specific gravity.
Hydriodic acid gas	4340
Chlorine acid „	2500
Carbonic acid „	1527
Nitrous oxide „	1527
Cyanogen „	1805
Oxygen „	1111
Carbonic oxide „	972
Carburetted hydrogen gas	972
Prussic acid „	937
Ammoniacal do. „	590
Steam of water „	623
Hydrogen „	69

Weight of water at the common temperature:

1 cubic inch = ·03617 lb.
1 „ foot = 62·5 „
1 „ „ = 6·25 imp. galls.
1·8 „ „ = 1 cwt.
1 cylindrical inch = ·02842 lb.
1 „ foot = 49·1 „
1 „ „ = 5 imp. galls.
2·282 feet = 1 cwt.
11·2 imp. gallons = 1 cwt.
224 „ „ = 1 ton.

WEIGHT OF A LINEAL FOOT OF SQUARE AND ROUND BAR IRON IN POUNDS.

Square iron.				Round iron.			
Inches square.	lbs.	Inches square.	lbs.	Inches diam.	lbs.	Inches diam.	lbs.
1/4	·208	2	13·33	1/4	·163	2	10·47
5/16	·325	2 1/8	15·05	5/16	·255	2 1/8	11·82
3/8	·468	2 1/4	16·87	3/8	·368	2 1/4	13·25
7/16	·638	2 3/8	18·80	7/16	·501	2 3/8	14·76
1/2	·833	2 1/2	20·81	1/2	·654	2 1/2	16·36
9/16	1·05	2 5/8	22·96	9/16	·828	2 5/8	18·03
5/8	1·30	2 3/4	25·20	5/8	1·02	2 3/4	19·79
11/16	1·57	2 7/8	27·55	11/16	1·23	2 7/8	21·63
3/4	1·87	3	30·00	3/4	1·47	3	23·56
13/16	2·20	3 1/8	32·55	13/16	1·72	3 1/8	25·56
7/8	2·55	3 1/4	35·20	7/8	2·00	3 1/4	27·65
15/16	2·92	3 3/8	37·96	15/16	2·30	3 3/8	29·82
1	3·33	3 1/2	40·80	1	2·61	3 1/2	32·07
1 1/16	3·76	3 5/8	43·81	1 1/16	2·95	3 5/8	34·40
1 1/8	4·21	3 3/4	46·87	1 1/8	3·31	3 3/4	36·81
1 3/16	4·70	3 7/8	50·05	1 3/16	3·69	3 7/8	39·31
1 1/4	5·20	4	53·33	1 1/4	4·09	4	41·88
1 5/16	5·74	4 1/4	60·20	1 5/16	4·51	4 1/4	47·28
1 3/8	6·30	4 1/2	67·50	1 3/8	4·95	4 1/2	53·01
1 7/16	6·88	4 3/4	75·20	1 7/16	5·40	4 3/4	59·06
1 1/2	7·50	5	83·33	1 1/2	5·89	5	65·45
1 9/16	8·15	5 1/4	92·43	1 9/16	6·40	5 1/4	72·61
1 5/8	8·80	5 1/2	101·03	1 5/8	6·91	5 1/2	79·36
1 11/16	9·50	5 3/4	110·40	1 11/16	7·46	5 3/4	86·73
1 3/4	10·20	6	120·21	1 3/4	8·01	6	94·60
1 13/16	10·69	6 1/2	130·20	1 13/16	8·60	6 1/2	110·60
1 7/8	11·71	7	151·81	1 7/8	9·20	7	128·28
1 15/16	12·52	8	213·29	1 15/16	9·33	8	167·51

Note.—The elastic power or direct tension of bar iron medium quality per square inch of cross section equals 10 tons; and a bar is extended ·000096, or nearly one ten-thousandth part of its length for every ton of direct strain per square inch of its sectional area: note, also, that either of the metals,—iron, tin, or zinc,—at a red heat, possesses the property of decomposing *water when in an aëriform state.*

WEIGHT OF A LINEAL FOOT OF FLAT BAR IRON IN POUNDS.

Breadth in inches.	Thickness in parts of an inch.						
	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$
$\frac{1}{2}$	·417	·52	—	—	—	—	—
$\frac{5}{8}$	·52	·65	·78	·91	—	—	—
$\frac{3}{4}$	·625	·785	·93	1·09	1·25	1·40	—
$\frac{7}{8}$	·725	·91	1·09	1·27	1·46	1·64	1·82
1	·834	1·04	1·25	1·45	1·67	1·87	2·08
$1\frac{1}{8}$	·937	1·17	1·40	1·64	1·87	2·10	2·34
$1\frac{1}{4}$	1·04	1·30	1·56	1·82	2·08	2·34	2·60
$1\frac{3}{8}$	1·14	1·43	1·71	2·00	2·29	2·57	2·86
$1\frac{1}{2}$	1·25	1·56	1·87	2·18	2·50	2·81	3·12
$1\frac{5}{8}$	1·35	1·69	2·03	2·36	2·70	3·04	3·38
$1\frac{3}{4}$	1·45	1·82	2·18	2·55	2·91	3·28	3·64
$1\frac{7}{8}$	1·56	1·95	2·34	2·73	3·12	3·51	3·90
2	1·66	2·08	2·50	2·91	3·33	3·75	4·16
$2\frac{1}{8}$	1·77	2·21	2·65	3·09	3·54	3·98	4·42
$2\frac{1}{4}$	1·87	2·34	2·81	3·28	3·75	4·21	4·68
$2\frac{3}{8}$	1·97	2·47	2·96	3·46	3·95	4·45	4·94
$2\frac{1}{2}$	2·08	2·60	3·12	3·64	4·16	4·68	5·20
$2\frac{5}{8}$	2·18	2·73	3·28	3·82	4·37	4·92	5·46
$2\frac{3}{4}$	2·29	2·86	3·43	4·01	4·58	5·15	5·72
$2\frac{7}{8}$	2·39	2·99	3·59	4·19	4·79	5·39	5·98
3	2·50	3·12	3·75	4·37	5·00	5·62	6·25
$3\frac{1}{4}$	2·70	3·38	4·06	4·73	5·41	6·09	6·77
$3\frac{1}{2}$	2·91	3·64	4·37	5·10	5·83	6·56	7·29
$3\frac{3}{4}$	3·12	3·90	4·68	5·46	6·25	7·03	7·81
4	3·33	4·16	5·00	5·83	6·66	7·50	8·33
$4\frac{1}{4}$	3·54	4·42	5·31	6·19	7·08	7·96	8·85
$4\frac{1}{2}$	3·75	4·68	5·62	6·56	7·50	8·43	9·37
$4\frac{3}{4}$	3·95	4·94	5·93	6·92	7·91	8·90	9·89
5	4·17	5·20	6·25	7·29	8·33	9·37	10·41
$5\frac{1}{4}$	4·37	5·46	6·56	7·65	8·75	9·84	10·93
$5\frac{1}{2}$	4·58	5·72	6·87	8·02	9·16	10·31	11·45
$5\frac{3}{4}$	4·79	5·98	7·18	8·38	9·58	10·78	11·97
6	5·	6·26	7·50	8·75	10·00	11·25	12·50

WEIGHT OF FLAT BAR IRON—*continued.*

Breadth in inches.	Thickness in parts of an inch.						
	$\frac{11}{16}$	$\frac{3}{4}$	$\frac{13}{16}$	$\frac{7}{8}$	$\frac{15}{16}$	1	$1\frac{1}{8}$
1	2·29	—	—	—	—	—	—
$1\frac{1}{8}$	2·57	2·81	3·04	—	—	—	—
$1\frac{1}{4}$	2·86	3·12	3·38	3·64	3·90	—	—
$1\frac{3}{8}$	3·15	3·43	3·72	4·01	4·29	4·58	—
$1\frac{1}{2}$	3·43	3·75	4·06	4·37	4·68	5·00	5·62
$1\frac{5}{8}$	3·72	4·06	4·40	4·73	5·07	5·41	6·08
$1\frac{3}{4}$	4·01	4·37	4·73	5·10	5·46	5·83	6·56
$1\frac{7}{8}$	4·29	4·68	5·07	5·46	5·85	6·25	7·02
2	4·58	5·00	5·41	5·83	6·25	6·66	7·50
$2\frac{1}{8}$	4·86	5·31	5·75	6·19	6·64	7·08	7·96
$2\frac{1}{4}$	5·15	5·62	6·09	6·56	7·03	7·50	8·43
$2\frac{3}{8}$	5·44	5·93	6·43	6·92	7·42	7·91	8·90
$2\frac{1}{2}$	5·72	6·25	6·77	7·29	7·81	8·33	9·36
$2\frac{5}{8}$	6·01	6·56	7·10	7·65	8·20	8·75	9·84
$2\frac{3}{4}$	6·30	6·87	7·44	8·02	8·59	9·16	10·30
$2\frac{7}{8}$	6·58	7·18	7·78	8·38	8·98	9·58	10·78
3	6·87	7·50	8·12	8·75	9·37	10·00	11·25
$3\frac{1}{4}$	7·44	8·12	8·80	9·47	10·15	10·83	12·18
$3\frac{1}{2}$	8·02	8·75	9·47	10·20	10·93	11·66	13·12
$3\frac{3}{4}$	8·59	9·37	10·15	10·93	11·71	12·50.	14·06
4	9·16	10·00	10·83	11·66	12·50	13·33	15·00
$4\frac{1}{4}$	9·73	10·62	11·51	12·39	13·28	14·16	15·92
$4\frac{1}{2}$	10·31	11·25	12·18	13·12	14·06	15·00	16·86
$4\frac{3}{4}$	10·88	11·87	12·86	13·85	14·84	15·83	17·80
5	11·45	12·50	13·54	14·58	15·62	16·66	18·75
$5\frac{1}{4}$	12·03	13·12	14·21	15·31	16·40	17·50	19·68
$5\frac{1}{2}$	12·60	13·75	14·89	16·04	17·18	18·33	20·62
$5\frac{3}{4}$	13·17	14·37	15·57	16·77	17·96	19·16	21·56
6	13·75	15·00	16·25	17·50	18·75	20·00	22·50
$6\frac{1}{2}$	14·88	16·24	17·60	18·95	20·30	21·66	24·36
7	16·04	17·50	18·94	20·41	21·86	23·33	26·24
$7\frac{1}{2}$	17·18	18·74	20·30	21·86	23·42	25·00	28·12
8	18·32	20·00	21·76	23·32	25·00	26·66	30·00

WEIGHT OF FLAT BAR IRON—*continued.*

Breadth in inches.	Thickness in inches.					
	1¼	1⅜	1½	1¾	2	2½
1½	6·24	6·86	—	—	—	—
1¾	7·28	8·02	8·74	—	—	—
2	8·32	9·16	10·00	11·66	—	—
2¼	9·36	10·30	11·24	13·12	15·00	—
2½	10·40	11·44	12·50	14·58	16·66	—
2¾	11·44	12·60	13·74	16·04	18·32	22·88
3	12·50	13·74	15·00	17·50	20·00	25·00
3¼	13·54	14·88	16·24	18·94	21·66	27·08
3½	14·58	16·04	17·50	20·40	23·32	29·16
3¾	15·62	17·18	18·74	21·86	25·00	31·24
4	16·66	18·32	20·00	23·32	26·66	33·32
4¼	17·70	19·46	21·24	25·78	28·32	35·40
4½	18·74	20·62	22·50	26·24	30·00	37·48
4¾	19·78	21·76	23·74	27·70	31·67	39·56
5	20·82	22·90	25·00	29·16	33·32	41·64
5¼	21·86	24·06	26·24	30·62	35·00	43·72
5½	22·90	25·20	27·50	32·08	36·66	45·80
5¾	23·94	26·34	28·74	33·54	38·32	47·88
6	25·00	27·50	30·00	35·00	40·00	50·00
6½	27·08	29·76	32·48	37·88	43·32	54·16
7	29·16	32·08	35·00	40·80	46·64	58·32
7½	31·24	34·36	37·48	43·72	50·00	62·48
8	33·32	36·64	40·00	46·64	53·32	66·64
8½	35·40	38·92	42·48	51·56	56·64	70·80
9	37·48	41·24	45·00	52·48	60·00	74·96

MECHANICAL TABLES

FOR THE USE OF OPERATIVE SMITHS, MILLWRIGHTS, AND ENGINEERS.

The following Tables, originally dedicated to 'the National Association of the Forgers of Iron-Work,' are, with permission, added to the present edition: they will be found extremely useful to Smiths generally, and are accompanied by Observations and Practical Examples.

TABLE I.*

DIAMETERS AND CIRCUMFERENCES OF CIRCLES

from One Inch to upwards of Twenty Feet, advancing by an Ei

Diameter.	Circumference.	Diameter.	Circumference.	Diameter.	Circumference.	Diameter.	C f
In.	Ft. In.	In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	F
1	0 3⅛	5	1 3⅝	0 9	2 4¼	1 1	3
1⅛	0 3½	5⅛	1 4	0 9⅛	2 4⅝	1 1⅛	3
1¼	0 3⅞	5¼	1 4⅜	0 9¼	2 5	1 1¼	3
1⅜	0 4¼	5⅜	1 4⅞	0 9⅜	2 5⅜	1 1⅜	3
1½	0 4⅝	5½	1 5¼	0 9½	2 5¾	1 1½	3
1⅝	0 5	5⅝	1 5⅝	0 9⅝	2 6⅛	1 1⅝	3
1¾	0 5⅜	5¾	1 6	0 9¾	2 6⅝	1 1¾	3
1⅞	0 5⅞	5⅞	1 6⅜	0 9⅞	2 7	1 1⅞	3
2	0 6¼	6	1 6¾	0 10	2 7⅜	1 2	3
2⅛	0 6⅝	6⅛	1 7¼	0 10⅛	2 7¾	1 2⅛	3
2¼	0 7	6¼	1 7⅝	0 10¼	2 8⅛	1 2¼	3
2⅜	0 7⅜	6⅜	1 8	0 10⅜	2 8½	1 2⅜	3
2½	0 7¾	6½	1 8⅜	0 10½	2 8⅞	1 2½	3
2⅝	0 8¼	6⅝	1 8¾	0 10⅝	2 9⅜	1 2⅝	3
2¾	0 8⅝	6¾	1 9⅛	0 10¾	2 9¾	1 2¾	3
2⅞	0 9	6⅞	1 9½	0 10⅞	2 10⅛	1 2⅞	3
3	0 9⅜	7	1 9⅞	0 11	2 10½	1 3	3
3⅛	0 9¾	7⅛	1 10⅜	0 11⅛	2 10⅞	1 3⅛	3
3¼	0 10⅛	7¼	1 10¾	0 11¼	2 11¼	1 3¼	3
3⅜	0 10½	7⅜	1 11⅛	0 11⅜	2 11⅝	1 3⅜	4
3½	0 10⅞	7½	1 11½	0 11½	3 0	1 3½	4
3⅝	0 11⅜	7⅝	1 11⅞	0 11⅝	3 0½	1 3⅝	4
3¾	0 11¾	7¾	2 0¼	0 11¾	3 0⅞	1 3¾	4
3⅞	1 0⅛	7⅞	2 0⅝	0 11⅞	3 1¼	1 3⅞	4
4	1 0½	8	2 1⅛	1 0	3 1⅝	1 4	4
4⅛	1 0⅞	8⅛	2 1½	1 0⅛	3 2	1 4⅛	4
4¼	1 1¼	8¼	2 1⅞	1 0¼	3 2⅜	1 4¼	4
4⅜	1 1⅝	8⅜	2 2¼	1 0⅜	3 2⅞	1 4⅜	4
4½	1 2⅛	8½	2 2⅝	1 0½	3 3¼	1 4½	4
4⅝	1 2½	8⅝	2 3	1 0⅝	3 3⅝	1 4⅝	4
4¾	1 2⅞	8¾	2 3⅜	1 0¾	3 4	1 4¾	4
4⅞	1 3¼	8⅞	2 3⅞	1 0⅞	3 4⅜	1 4⅞	4

* James Foden.

Diam.		Circum.		Diam.		Circum.		Diam.		Circum.		Diam.		Circum.	
Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.
1	5	4	5⅜	1	9⅜	5	7⅛	2	1¾	6	8⅞	2	6⅛	7	10⅝
1	5⅛	4	5¾	1	9½	5	7½	2	1⅞	6	9¼	2	6¼	7	11
1	5¼	4	6⅛	1	9⅝	5	8	2	2	6	9⅝	2	6⅜	7	11⅜
1	5⅜	4	6½	1	9¾	5	8⅜	2	2⅛	6	10	2	6½	7	11¾
1	5½	4	6⅞	1	9⅞	5	8¾	2	2¼	6	10⅜	2	6⅝	8	0⅛
1	5⅝	4	7⅜	1	10	5	9	2	2⅜	6	10¾	2	6¾	8	0½
1	5¾	4	7¾	1	10⅛	5	9½	2	2½	6	11¼	2	6⅞	8	0⅞
1	5⅞	4	8⅛	1	10¼	5	9⅞	2	2⅝	6	11⅝	2	7	8	1⅜
1	6	4	8½	1	10⅜	5	10¼	2	2¾	7	0	2	7⅛	8	1¾
1	6⅛	4	8⅞	1	10½	5	10⅝	2	2⅞	7	0⅜	2	7¼	8	2⅛
1	6¼	4	9¼	1	10⅝	5	11	2	3	7	0¾	2	7⅜	8	2½
1	6⅜	4	9⅝	1	10¾	5	11⅜	2	3⅛	7	1⅛	2	7½	8	2⅞
1	6½	4	10	1	10⅞	5	11¾	2	3¼	7	1½	2	7⅝	8	3¼
1	6⅝	4	10⅜	1	11	6	0¼	2	3⅜	7	2	2	7¾	8	3¾
1	6¾	4	10⅞	1	11⅛	6	0⅝	2	3½	7	2⅜	2	7⅞	8	4⅛
1	6⅞	4	11¼	1	11¼	6	1	2	3⅝	7	2¾	2	8	8	4½
1	7	4	11⅝	1	11⅜	6	1⅜	2	3¾	7	3⅛	2	8⅛	8	4⅞
1	7⅛	5	0	1	11½	6	1¾	2	3⅞	7	3½	2	8¼	8	5¼
1	7¼	5	0⅜	1	11⅝	6	2⅛	2	4	7	3⅞	2	8⅜	8	5⅝
1	7⅜	5	0⅞	1	11¾	6	2½	2	4⅛	7	4¼	2	8½	8	6
1	7½	5	1¼	1	11⅞	6	3	2	4¼	7	4¾	2	8⅝	8	6½
1	7⅝	5	1⅝	2	0	6	3⅜	2	4⅜	7	5⅛	2	8¾	8	6⅞
1	7¾	5	2	2	0⅛	6	3¾	2	4½	7	5½	2	8⅞	8	7¼
1	7⅞	5	2⅜	2	0¼	6	4⅛	2	4⅝	7	5⅞	2	9	8	7⅝
1	8	5	2¾	2	0⅜	6	4½	2	4¾	7	6¼	2	9⅛	8	8
1	8⅛	5	3⅛	2	0½	6	4⅞	2	4⅞	7	6⅝	2	9¼	8	8⅜
1	8¼	5	3⅝	2	0⅝	6	5¼	2	5	7	7	2	9⅜	8	8¾
1	8⅜	5	4	2	0¾	6	5¾	2	5⅛	7	7½	2	9½	8	9¼
1	8½	5	4⅜	2	0⅞	6	6⅛	2	5¼	7	7⅞	2	9⅝	8	9⅝
1	8⅝	5	4¾	2	1	6	6½	2	5⅜	7	8¼	2	9¾	8	10
1	8¾	5	5⅛	2	1⅛	6	6⅞	2	5½	7	8⅝	2	9⅞	8	10⅜
1	8⅞	5	5½	2	1¼	6	7¼	2	5⅝	7	9	2	10	8	10¾
1	9	5	5⅞	2	1⅜	6	7⅝	2	5¾	7	9⅜	2	10⅛	8	11⅛
1	9⅛	5	6⅜	2	1½	6	8	2	5⅞	7	9¾	2	10¼	8	11½
1	9¼	5	6¾	2	1⅝	6	8½	2	6	7	10⅛	2	10⅜	8	11⅞

Diam. Ft.	Diam. In.	Circum. Ft.	Circum. In.
2	10½	9	0⅜
2	10⅝	9	0¾
2	10¾	9	1⅛
2	10⅞	9	1½
2	11	9	1⅞
2	11⅛	9	2¼
2	11¼	9	2⅝
2	11⅜	9	3
2	11½	9	3⅜
2	11⅝	9	3⅞
2	11¾	9	4¼
2	11⅞	9	4⅝
3	0	9	5
3	0⅛	9	5⅜
3	0¼	9	5⅞
3	0⅜	9	6¼
3	0½	9	6⅝
3	0⅝	9	7
3	0¾	9	7⅜
3	0⅞	9	7¾
3	1	9	8⅛
3	1⅛	9	8⅝
3	1¼	9	9
3	1⅜	9	9⅜
3	1½	9	9¾
3	1⅝	9	10⅛
3	1¾	9	10½
3	1⅞	9	10⅞
3	2	9	11⅜
3	2⅛	9	11¾
3	2¼	10	0⅛
3	2⅜	10	0½
3	2½	10	0⅞
3	2⅝	10	1¼
3	2¾	10	1⅝

Diam. Ft.	Diam. In.	Circum. Ft.	Circum. In.
3	2⅞	10	2⅛
3	3	10	2½
3	3⅛	10	2⅞
3	3¼	10	3¼
3	3⅜	10	3⅝
3	3½	10	4
3	3⅝	10	4⅜
3	3¾	10	4⅞
3	3⅞	10	5¼
3	4	10	5⅝
3	4⅛	10	6
3	4¼	10	6⅜
3	4⅜	10	6¾
3	4½	10	7⅛
3	4⅝	10	7⅝
3	4¾	10	8
3	4⅞	10	8⅜
3	5	10	8¾
3	5⅛	10	9⅛
3	5¼	10	9½
3	5⅜	10	9⅞
3	5½	10	10⅜
3	5⅝	10	10¾
3	5¾	10	11⅛
3	5⅞	10	11½
3	6	10	11⅞
3	6⅛	11	0¼
3	6¼	11	0⅝
3	6⅜	11	1⅛
3	6½	11	1½
3	6⅝	11	1⅞
3	6¾	11	2¼
3	6⅞	11	2⅝
3	7	11	3

Diam. Ft.	Diam. In.	Circum. Ft.	Circum. In.
3	7⅛	11	3⅜
3	7¼	11	3⅞
3	7⅜	11	4¼
3	7½	11	4⅝
3	7⅝	11	5
3	7¾	11	5⅜
3	7⅞	11	5¾
3	8	11	6⅛
3	8⅛	11	6½
3	8¼	11	7
3	8⅜	11	7⅜
3	8½	11	7¾
3	8⅝	11	8⅛
3	8¾	11	8½
3	8⅞	11	8⅞
3	9	11	9¼
3	9⅛	11	9¾
3	9¼	11	10⅛
3	9⅜	11	10½
3	9½	11	10⅞
3	9⅝	11	11¼
3	9¾	11	11⅝
3	9⅞	12	0
3	10	12	0½
3	10⅛	12	0⅞
3	10¼	12	1¼
3	10⅜	12	1⅝
3	10½	12	2
3	10⅝	12	2⅜
3	10¾	12	2¾
3	10⅞	12	3¼
3	11	12	3⅝
3	11⅛	12	4
3	11¼	12	4⅜
3	11⅜	12	4¾

Circum. Ft. In.	Diam. Ft. In.	Circum. Ft. In.	Diam. Ft. In.	Circum. Ft. In.	Diam. Ft. In.	Circum. Ft. In.
13 6⅞	4 8⅛	14 8¼	5 0½	15 10	5 4⅞	16 11¾
13 7¼	4 8¼	14 8⅝	5 0⅝	15 10⅜	5 5	17 0⅛
13 7⅝	4 8⅜	14 9	5 0¾	15 10¾	5 5⅛	17 0⅝
13 8⅛	4 8½	14 9⅜	5 0⅞	15 11⅛	5 5¼	17 1
13 8½	4 8⅝	14 9⅞	5 1	15 11⅝	5 5⅜	17 1⅜
13 8⅞	4 8¾	14 10¼	5 1⅛	16 0	5 5½	17 1¾
13 9¼	4 8⅞	14 10⅝	5 1¼	16 0⅜	5 5⅝	17 2⅛
13 9⅝	4 9	14 11	5 1⅜	16 0¾	5 5¾	17 2½
13 10	4 9⅛	14 11⅜	5 1½	16 1⅛	5 5⅞	17 2⅞
13 10⅜	4 9¼	14 11¾	5 1⅝	16 1½	5 6	17 3¼
13 10⅞	4 9⅜	15 0⅛	5 1¾	16 1⅞	5 6⅛	17 3⅝
13 11¼	4 9½	15 0⅝	5 1⅞	16 2⅜	5 6¼	17 4⅛
13 11⅝	4 9⅝	15 1	5 2	16 2¾	5 6⅜	17 4½
14 0	4 9¾	15 1⅜	5 2⅛	16 3⅛	5 6½	17 4⅞
14 0⅜	4 9⅞	15 1¾	5 2¼	16 3½	5 6⅝	17 5¼
14 0⅞	4 10	15 2⅛	5 2⅜	16 3⅞	5 6¾	17 5⅝
14 1¼	4 10⅛	15 2½	5 2½	16 4¼	5 6⅞	17 6
14 1⅝	4 10¼	15 2⅞	5 2⅝	16 4⅝	5 7	17 6⅜
14 2	4 10⅜	15 3⅜	5 2¾	16 5⅛	5 7⅛	17 6⅞
14 2⅜	4 10½	15 3¾	5 2⅞	16 5½	5 7¼	17 7¼
14 2¾	4 10⅝	15 4⅛	5 3	16 5⅞	5 7⅜	17 7⅝
14 3⅛	4 10¾	15 4½	5 3⅛	16 6¼	5 7½	17 8
14 3½	4 10⅞	15 4⅞	5 3¼	16 6⅝	5 7⅝	17 8⅜
14 4	4 11	15 5¼	5 3⅜	16 7	5 7¾	17 8¾
14 4⅜	4 11⅛	15 5⅝	5 3½	16 7⅜	5 7⅞	17 9⅛
14 4¾	4 11¼	15 6⅛	5 3⅝	16 7⅞	5 8	17 9⅝
14 5⅛	4 11⅜	15 6½	5 3¾	16 8¼	5 8⅛	17 10
14 5½	4 11½	15 6⅞	5 3⅞	16 8⅝	5 8¼	17 10⅜
14 5⅞	4 11⅝	15 7¼	5 4	16 9	5 8⅜	17 10¾
14 6¼	4 11¾	15 7⅝	5 4⅛	16 9⅜	5 8½	17 11⅛
14 6¾	4 11⅞	15 8	5 4¼	16 9¾	5 8⅝	17 11½
14 7⅛	5 0	15 8⅜	5 4⅜	16 10⅛	5 8¾	17 11⅞
14 7½	5 0⅛	15 8⅞	5 4½	16 10⅝	5 8⅞	18 0⅜
14 7⅞	5 0¼	15 9¼	5 4⅝	16 11	5 9	18 0¾
	5 0⅜	15 9⅝	5 4¾	16 11⅜		

Diam. Ft.	Diam. In.	Circum. Ft.	Circum. In.
5	9⅛	18	1⅛
5	9¼	18	1½
5	9⅜	18	1⅞
5	9½	18	2¼
5	9⅝	18	2⅝
5	9¾	18	3
5	9⅞	18	3⅜
5	10	18	3⅞
5	10⅛	18	4¼
5	10¼	18	4⅝
5	10⅜	18	5
5	10½	18	5⅜
5	10⅝	18	5⅞
5	10¾	18	6¼
5	10⅞	18	6⅝
5	11	18	7
5	11⅛	18	7⅜
5	11¼	18	7¾
5	11⅜	18	8⅛
5	11½	18	8½
5	11⅝	18	9
5	11¾	18	9⅜
5	11⅞	18	9¾
6	0	18	10⅛
6	0⅛	18	10½
6	0¼	18	10⅞
6	0⅜	18	11¼
6	0½	18	11¾
6	0⅝	19	0⅛
6	0¾	19	0½
6	0⅞	19	0⅞
6	1	19	1¼
6	1⅛	19	1⅝
6	1¼	19	2
6	1⅜	19	2½

Diam. Ft.	Diam. In.	Circum. Ft.	Circum. In.
6	1½	19	2⅞
6	1⅝	19	3¼
6	1¾	19	3⅝
6	1⅞	19	4
6	2	19	4⅜
6	2⅛	19	4⅞
6	2¼	19	5¼
6	2⅜	19	5⅝
6	2½	19	6
6	2⅝	19	6⅜
6	2¾	19	6¾
6	2⅞	19	7⅛
6	3	19	7½
6	3⅛	19	8
6	3¼	19	8⅜
6	3⅜	19	8¾
6	3½	19	9⅛
6	3⅝	19	9½
6	3¾	19	9⅞
6	3⅞	19	10¼
6	4	19	10¾
6	4⅛	19	11⅛
6	4¼	19	11½
6	4⅜	19	11⅞
6	4½	20	0¼
6	4⅝	20	0⅝
6	4¾	20	1
6	4⅞	20	1½
6	5	20	1⅞
6	5⅛	20	2¼
6	5¼	20	2⅝
6	5⅜	20	3
6	5½	20	3⅜
6	5⅝	20	3¾
6	5¾	20	4¼

Diam. Ft.	Diam. In.	Circum. Ft.	Circum. In.
6	5⅞	20	4⅝
6	6	20	5
6	6⅛	20	5⅜
6	6¼	20	5¾
6	6⅜	20	6⅛
6	6½	20	6½
6	6⅝	20	7
6	6¾	20	7⅜
6	6⅞	20	7¾
6	7	20	8⅛
6	7⅛	20	8½
6	7¼	20	8⅞
6	7⅜	20	9¼
6	7½	20	9¾
6	7⅝	20	10⅛
6	7¾	20	10½
6	7⅞	20	10⅞
6	8	20	11¼
6	8⅛	20	11⅝
6	8¼	21	0
6	8⅜	21	0½
6	8½	21	0⅞
6	8⅝	21	1¼
6	8¾	21	1⅝
6	8⅞	21	2
6	9	21	2⅜
6	9⅛	21	2⅞
6	9¼	21	3¼
6	9⅜	21	3⅝
6	9½	21	4
6	9⅝	21	4⅜
6	9¾	21	4¾
6	9⅞	21	5⅛
6	10	21	5½

Diam. Ft.	Diam. In.	Circum. Ft.	Circum. In.
6	10⅛	21	
6	10¼	21	
6	10⅜	21	
6	10½	21	
6	10⅝	21	
6	10¾	21	
6	10⅞	21	
6	11	21	
6	11⅛	21	
6	11¼	21	
6	11⅜	21	
6	11½	21	
6	11⅝	21	
6	11¾	21	
6	11⅞	21	
7	0	21	
7	0⅛	22	
7	0¼	22	
7	0⅜	22	
7	0½	22	
7	0⅝	22	
7	0¾	22	
7	0⅞	22	
7	1	22	
7	1⅛	22	
7	1¼	22	
7	1⅜	22	
7	1½	22	
7	1⅝	22	
7	1¾	22	
7	1⅞	22	
7	2	22	
7	2⅛	22	
7	2¼	22	
7	2⅜	22	

Diam. Ft.	Diam. In.	Circum. Ft.	Circum. In.
7	2½	22	7⅝
7	2⅝	22	8⅛
7	2¾	22	8½
7	2⅞	22	8⅞
7	3	22	9¼
7	3⅛	22	9⅝
7	3¼	22	10
7	3⅜	22	10⅜
7	3½	22	10⅞
7	3⅝	22	11¼
7	3¾	22	11⅝
7	3⅞	23	0
7	4	23	0⅜
7	4⅛	23	0¾
7	4¼	23	1⅛
7	4⅜	23	1⅝
7	4½	23	2
7	4⅝	23	2⅜
7	4¾	23	2¾
7	4⅞	23	3⅛
7	5	23	3½
7	5⅛	23	3⅞
7	5¼	23	4⅜
7	5⅜	23	4¾
7	5½	23	5⅛
7	5⅝	23	5½
7	5¾	23	5⅞
7	5⅞	23	6¼
7	6	23	6⅝
7	6⅛	23	7⅛
7	6¼	23	7½
7	6⅜	23	7⅞
7	6½	23	8¼
7	6⅝	23	8⅝
7	6¾	23	9

Diam. Ft.	Diam. In.	Circum. Ft.	Circum. In.
7	6⅞	23	9⅜
7	7	23	9⅞
7	7⅛	23	10¼
7	7¼	23	10⅝
7	7⅜	23	11
7	7½	23	11⅜
7	7⅝	23	11¾
7	7¾	24	0⅛
7	7⅞	24	0⅝
7	8	24	1
7	8⅛	24	1⅜
7	8¼	24	1¾
7	8⅜	24	2⅛
7	8½	24	2½
7	8⅝	24	2⅞
7	8¾	24	3⅜
7	8⅞	24	3¾
7	9	24	4⅛
7	9⅛	24	4½
7	9¼	24	4⅞
7	9⅜	24	5¼
7	9½	24	5⅝
7	9⅝	24	6⅛
7	9¾	24	6½
7	9⅞	24	6⅞
7	10	24	7¼
7	10⅛	24	7⅝
7	10¼	24	8
7	10⅜	24	8⅜
7	10½	24	8⅞
7	10⅝	24	9¼
7	10¾	24	9⅝
7	10⅞	24	10
7	11	24	10⅜

Diam. Ft.	Diam. In.	Circum. Ft.	Circum. In.
7	11⅛	24	10¾
7	11¼	24	11⅛
7	11⅜	24	11½
7	11½	25	0
7	11⅝	25	0⅜
7	11¾	25	0¾
7	11⅞	25	1⅛
8	0	25	1½
8	0⅛	25	1⅞
8	0¼	25	2⅜
8	0⅜	25	2¾
8	0½	25	3⅛
8	0⅝	25	3½
8	0¾	25	3⅞
8	0⅞	25	4¼
8	1	25	4⅝
8	1⅛	25	5⅛
8	1¼	25	5½
8	1⅜	25	5⅞
8	1½	25	6¼
8	1⅝	25	6⅝
8	1¾	25	7
8	1⅞	25	7⅜
8	2	25	7⅞
8	2⅛	25	8¼
8	2¼	25	8⅝
8	2⅜	25	9
8	2½	25	9⅜
8	2⅝	25	9¾
8	2¾	25	10⅛
8	2⅞	25	10½
8	3	25	11
8	3⅛	25	11⅜
8	3¼	25	11¾
8	3⅜	26	0⅛

Diam. Ft.	Diam. In.	Circum. Ft.	Circum. In.
8	3½	26	0½
8	3⅝	26	0⅞
8	3¾	26	1⅜
8	3⅞	26.	1¾
8	4	26	2⅛
8	4⅛	26	2½
8	4¼	26	2⅞
8	4⅜	26	3¼
8	4½	26	3⅝
8	4⅝	26	4⅛
8	4¾	26	4½
8	4⅞	26	4⅞
8	5	26	5¼
8	5⅛	26	5⅝
8	5¼	26	6
8	5⅜	26	6⅜
8	5½	26	6¾
8	5⅝	26	7¼
8	5¾	26	7⅝
8	5⅞	26	8
8	6	26	8⅜
8	6⅛	26	8¾
8	6¼	26	9⅛
8	6⅜	26	9½
8	6½	26	10
8	6⅝	26	10⅜
8	6¾	26	10¾
8	6⅞	26	11⅛
8	7	26	11½
8	7⅛	26	11⅞
8	7¼	27	0¼
8	7⅜	27	0¾
8	7½	27	1⅛
8	7⅝	27	1½
8	7¾	27	1⅞

Diam. Ft.	Diam. In.	Circum. Ft.	Circum. In.
8	7⅞	27	2¼
8	8	27	2⅝
8	8⅛	27	3
8	8¼	27	3½
8	8⅜	27	3⅞
8	8½	27	4¼
8	8⅝	27	4⅝
8	8¾	27	5
8	8⅞	27	5⅜
8	9	27	5¾
8	9⅛	27	6¼
8	9¼	27	6⅝
8	9⅜	27	7
8	9½	27	7⅜
8	9⅝	27	7¾
8	9¾	27	8⅛
8	9⅞	27	8½
8	10	27	9
8	10⅛	27	9⅜
8	10¼	27	9¾
8	10⅜	27	10⅛
8	10½	27	10½
8	10⅝	27	10⅞
8	10¾	27	11¼
8	10⅞	27	11¾
8	11	28	0⅛
8	11⅛	28	0½
8	11¼	28	0⅞
8	11⅜	28	1¼
8	11½	28	1⅝
8	11⅝	28	2
8	11¾	28	2½
8	11⅞	28	2⅞
9	0	28	3¼

Diam. Ft.	Diam. In.	Circum. Ft.	Circum. In.
9	0⅛	28	3⅝
9	0¼	28	4
9	0⅜	28	4⅜
9	0½	28	4¾
9	0⅝	28	5¼
9	0¾	28	5⅝
9	0⅞	28	6
9	1	28	6⅜
9	1⅛	28	6¾
9	1¼	28	7⅛
9	1⅜	28	7½
9	1½	28	8
9	1⅝	28	8⅜
9	1¾	28	8¾
9	1⅞	28	9⅛
9	2	28	9½
9	2⅛	28	9⅞
9	2¼	28	10¼
9	2⅜	28	10¾
9	2½	28	11⅛
9	2⅝	28	11½
9	2¾	28	11⅞
9	2⅞	29	0¼
9	3	29	0⅝
9	3⅛	29	1
9	3¼	29	1½
9	3⅜	29	1⅞
9	3½	29	2¼
9	3⅝	29	2⅝
9	3¾	29	3
9	3⅞	29	3⅜
9	4	29	3¾
9	4⅛	29	4¼
9	4¼	29	4⅝
9	4⅜	29	5

Diam. Ft.	Diam. In.	Circum. Ft.	Circum. In.
9	4½	29	5⅜
9	4⅝	29	5¾
9	4¾	29	6⅛
9	4⅞	29	6½
9	5	29	7
9	5⅛	29	7⅜
9	5¼	29	7¾
9	5⅜	29	8⅛
9	5½	29	8½
9	5⅝	29	8⅞
9	5¾	29	9¼
9	5⅞	29	9¾
9	6	29	10⅛
9	6⅛	29	10½
9	6¼	29	10⅞
9	6⅜	29	11¼
9	6½	29	11⅝
9	6⅝	30	0
9	6¾	30	0½
9	6⅞	30	0⅞
9	7	30	1¼
9	7⅛	30	1⅝
9	7¼	30	2
9	7⅜	30	2⅜
9	7½	30	2¾
9	7⅝	30	3⅛
9	7¾	30	3⅝
9	7⅞	30	4
9	8	30	4⅜
9	8⅛	30	4¾
9	8¼	30	5⅛
9	8⅜	30	5½
9	8½	30	6
9	8⅝	30	6⅜
9	8¾	30	6¾

Diam. Ft.	Diam. In.	Cir Ft.
9	8⅞	30
9	9	30
9	9⅛	30
9	9¼	30
9	9⅜	30
9	9½	30
9	9⅝	30
9	9¾	30
9	9⅞	30
9	10	30
9	10⅛	30
9	10¼	30
9	10⅜	30
9	10½	31
9	10⅝	31
9	10¾	31
9	10⅞	31
9	11	31
9	11⅛	31
9	11¼	31
9	11⅜	31
9	11½	31
9	11⅝	31
9	11¾	31
9	11⅞	31
10	0	31
10	0⅛	31
10	0¼	31
10	0⅜	31
10	0½	31
10	0⅝	31
10	0¾	31
10	0⅞	31
10	1	31

...	Circum.		Diam.		Circum.		Diam.		Circum.		Diam.		Circum.	
n.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.
1⅛	31	8½	10	5½	32	10¼	10	9⅞	34	0	11	2⅛	35	1¼
1¼	31	8⅞	10	5⅝	32	10⅝	10	10	34	0⅜	11	2¼	35	1¾
1⅜	31	9¼	10	5¾	32	11	10	10⅛	34	0¾	11	2⅜	35	2⅛
1½	31	9⅝	10	5⅞	32	11⅜	10	10¼	34	1⅛	11	2½	35	2½
1⅝	31	10	10	6	32	11¾	10	10⅜	34	1½	11	2⅝	35	2⅞
1¾	31	10⅜	10	6⅛	33	0⅛	10	10½	34	1⅞	11	2¾	35	3¼
1⅞	31	10⅞	10	6¼	33	0⅝	10	10⅝	34	2⅜	11	2⅞	35	3⅝
2	31	11¼	10	6⅜	33	1	10	10¾	34	2¾	11	3	35	4
2⅛	31	11⅝	10	6½	33	1⅜	10	10⅞	34	3⅛	11	3⅛	35	4½
2¼	32	0	10	6⅝	33	1¾	10	11	34	3½	11	3¼	35	4⅞
2⅜	32	0⅜	10	6¾	33	2⅛	10	11⅛	34	3⅞	11	3⅜	35	5¼
2½	32	0¾	10	6⅞	33	2½	10	11¼	34	4¼	11	3½	35	5⅝
2⅝	32	1⅛	10	7	33	2⅞	10	11⅜	34	4⅝	11	3⅝	35	6
2¾	32	1½	10	7⅛	33	3⅜	10	11½	34	5	11	3¾	35	6⅜
2⅞	32	2	10	7¼	33	3¾	10	11⅝	34	5½	11	3⅞	35	6¾
3	32	2⅜	10	7⅜	33	4⅛	10	11¾	34	5⅞	11	4	35	7¼
3⅛	32	2¾	10	7½	33	4½	10	11⅞	34	6¼	11	4⅛	35	7⅝
3¼	32	3⅛	10	7⅝	33	4⅞	11	0	34	6⅝	11	4¼	35	8
3⅜	32	3½	10	7¾	33	5¼	11	0⅛	34	7	11	4⅜	35	8⅜
3½	32	3⅞	10	7⅞	33	5⅝	11	0¼	34	7⅜	11	4½	35	8¾
3⅝	32	4⅜	10	8	33	6⅛	11	0⅜	34	7¾	11	4⅝	35	9⅛
3¾	32	4¾	10	8⅛	33	6½	11	0½	34	8¼	11	4¾	35	9½
3⅞	32	5⅛	10	8¼	33	6⅞	11	0⅝	34	8⅝	11	4⅞	35	10
4	32	5½	10	8⅜	33	7¼	11	0¾	34	9	11	5	35	10⅜
4⅛	32	5⅞	10	8½	33	7⅝	11	0⅞	34	9⅜	11	5⅛	35	10¾
4¼	32	6¼	10	8⅝	33	8	11	1	34	9¾	11	5¼	35	11⅛
4⅜	32	6⅝	10	8¾	33	8⅜	11	1⅛	34	10⅛	11	5⅜	35	11½
4½	32	7	10	8⅞	33	8⅞	11	1¼	34	10½	11	5½	35	11⅞
4⅝	32	7½	10	9	33	9¼	11	1⅜	34	11	11	5⅝	36	0¼
4¾	32	7⅞	10	9⅛	33	9⅝	11	1½	34	11⅜	11	5¾	36	0¾
4⅞	32	8¼	10	9¼	33	10	11	1⅝	34	11¾	11	5⅞	36	1⅛
5	32	8⅝	10	9⅜	33	10⅜	11	1¾	35	0⅛	11	6	36	1½
5⅛	32	9	10	9½	33	10¾	11	1⅞	35	0½	11	6⅛	36	1⅞
5¼	32	9⅜	10	9⅝	33	11⅛	11	2	35	0⅞	11	6¼	36	2¼
5⅜	32	9⅞	10	9¾	33	11½					11	6⅜	36	2⅝

Diam.		Circum.		Diam.		Circum.		Diam.		Circum.		Di
Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.
11	6½	36	3	11	10⅞	37	4¾	12	3⅛	38	6⅛	12
11	6⅝	36	3½	11	11	37	5¼	12	3¼	38	6½	12
11	6¾	36	3⅞					12	3⅜	38	6⅞	12
11	6⅞	36	4¼	11	11⅛	37	5⅝	12	3½	38	7⅜	12
11	7	36	4⅝	11	11¼	37	6	12	3⅝	38	7¾	12
11	7⅛	36	5	11	11⅜	37	6⅜	12	3¾	38	8⅛	12
11	7¼	36	5⅜	11	11½	37	6¾	12	3⅞	38	8½	12
11	7⅜	36	5⅞	11	11⅝	37	7⅛	12	4	38	8⅞	12
11	7½	36	6¼	11	11¾	37	7½	12	4⅛	38	9¼	12
11	7⅝	36	6⅝	11	11⅞	37	7⅞	12	4¼	38	9⅝	12
11	7¾	36	7	12	0	37	8⅜	12	4⅜	38	10⅛	12
11	7⅞	36	7⅜	12	0⅛	37	8¾	12	4½	38	10½	12
11	8	36	7¾	12	0¼	37	9⅛	12	4⅝	38	10⅞	12
11	8⅛	36	8⅛	12	0⅜	37	9½	12	4¾	38	11¼	12
11	8¼	36	8½	12	0½	37	9⅞	12	4⅞	38	11⅝	12
11	8⅜	36	9	12	0⅝	37	10¼	12	5	39	0	12
11	8½	36	9⅜	12	0¾	37	10⅝	12	5⅛	39	0⅜	12
11	8⅝	36	9¾	12	0⅞	37	11⅛	12	5¼	39	0⅞	12
11	8¾	36	10⅛	12	1	37	11½	12	5⅜	39	1¼	12
11	8⅞	36	10½	12	1⅛	37	11¾	12	5½	39	1⅝	12
11	9	36	10⅞	12	1¼	38	0¼	12	5⅝	39	2	12
11	9⅛	36	11¼	12	1⅜	38	0⅝	12	5¾	39	2⅜	12
11	9¼	36	11¾	12	1½	38	1	12	5⅞	39	2¾	12
11	9⅜	37	0⅛	12	1⅝	38	1⅜	12	6	39	3⅛	12
11	9½	37	0½	12	1¾	38	1⅞	12	6⅛	39	3⅝	12
11	9⅝	37	0⅞	12	1⅞	38	2¼	12	6¼	39	4	12
11	9¾	37	1¼	12	2	38	2⅝	12	6⅜	39	4⅜	12
11	9⅞	37	1⅝	12	2⅛	38	3	12	6½	39	4¾	12
11	10	37	2	12	2¼	38	3⅜	12	6⅝	39	5⅛	12
11	10⅛	37	2½	12	2⅜	38	3¾	12	6¾	39	5½	12
11	10¼	37	2⅞	12	2½	38	4⅛	12	6⅞	39	5⅞	12
11	10⅜	37	3¼	12	2⅝	38	4⅝	12	7	39	6⅜	12
11	10½	37	3⅝	12	2¾	38	5	12	7⅛	39	6¾	12
11	10⅝	37	4	12	2⅞	38	5⅜	12	7¼	39	7⅛	12
11	10¾	37	4⅜	12	3	38	5¾	12	7⅜	39	7½	12

Circum. Ft.	Circum. In.
40	9⅝
40	10
40	10⅜
40	10⅞
40	11¼
40	11⅝
41	0
41	0⅜
41	0¾
41	1⅛
41	1½
41	2
41	2⅜
41	2¾
41	3⅛
41	3½
41	3⅞
41	4¼
41	4¾
41	5⅛
41	5½
41	5⅞
41	6¼
41	6⅝
41	7
41	7½
41	7⅞
41	8¼
41	8⅝
41	9
41	9⅜
41	9¾
41	10¼
41	10⅝

Diam. Ft.	Diam. In.	Circum. Ft.	Circum. In.
13	4⅛	41	11
13	4¼	41	11⅜
13	4⅜	41	11¾
13	4½	42	0⅛
13	4⅝	42	0½
13	4¾	42	1
13	4⅞	42	1⅜
13	5	42	1¾
13	5⅛	42	2⅛
13	5¼	42	2½
13	5⅜	42	2⅞
13	5½	42	3¼
13	5⅝	42	3¾
13	5¾	42	4⅛
13	5⅞	42	4½
13	6	42	4⅞
13	6⅛	42	5¼
13	6¼	42	5⅝
13	6⅜	42	6
13	6½	42	6½
13	6⅝	42	6⅞
13	6¾	42	7¼
13	6⅞	42	7⅝
13	7	42	8
13	7⅛	42	8⅜
13	7¼	42	8⅞
13	7⅜	42	9¼
13	7½	42	9⅝
13	7⅝	42	10
13	7¾	42	10⅜
13	7⅞	42	10¾
13	8	42	11⅛
13	8⅛	42	11½
13	8¼	43	0
13	8⅜	43	0⅜

Diam. Ft.	Diam. In.	Circum. Ft.	Circum. In.
13	8½	43	0¾
13	8⅝	43	1⅛
13	8¾	43	1½
13	8⅞	43	1⅞
13	9	43	2¼
13	9⅛	43	2⅝
13	9¼	43	3⅛
13	9⅜	43	3½
13	9½	43	3⅞
13	9⅝	43	4¼
13	9¾	43	4⅝
13	9⅞	43	5
13	10	43	5½
13	10⅛	43	5⅞
13	10¼	43	6¼
13	10⅜	43	6⅝
13	10½	43	7
13	10⅝	43	7⅜
13	10¾	45	7¾
13	10⅞	43	8¼
13	11	43	8⅝
13	11⅛	43	9
13	11¼	43	9⅜
13	11⅜	43	9¾
13	11½	43	10⅛
13	11⅝	43	10½
13	11¾	43	11
13	11⅞	43	11⅜
14	0	43	11¾
14	0⅛	44	0⅛
14	0¼	44	0½
14	0⅜	44	0⅞
14	0½	44	1¼
14	0⅝	44	1¾
14	0¾	44	2⅛

Diam. Ft.	Diam. In.	Circum. Ft.	Circum. In.
14	0⅞	44	2½
14	1	44	2⅞
14	1⅛	44	3¼
14	1¼	44	3⅝
14	1⅜	44	4
14	1½	44	4½
14	1⅝	44	4⅞
14	1¾	44	5¼
14	1⅞	44	5⅝
14	2	44	6
14	2⅛	44	6⅜
14	2¼	44	6⅞
14	2⅜	44	7¼
14	2½	44	7⅝
14	2⅝	44	8
14	2¾	44	8⅜
14	2⅞	44	8¾
14	3	44	9⅛
14	3⅛	44	9½
14	3¼	44	9⅞
14	3⅜	44	10⅜
14	3½	44	10¾
14	3⅝	44	11⅛
14	3¾	44	11½
14	3⅞	44	11⅞
14	4	45	0¼
14	4⅛	45	0⅝
14	4¼	45	1⅛
14	4⅜	45	1½
14	4½	45	1⅞
14	4⅝	45	2¼
14	4¾	45	2⅝
14	4⅞	45	3
14	5	45	3⅜

Diam. Ft.	Diam. In.	Circum. Ft.	Circum. In.
14	5⅛	45	3⅞
14	5¼	45	4¼
14	5⅜	45	4⅝
14	5½	45	5
14	5⅝	45	5⅜
14	5¾	45	5¾
14	5⅞	45	6¼
14	6	45	6⅝
14	6⅛	45	7
14	6¼	45	7⅜
14	6⅜	45	7¾
14	6½	45	8⅛
14	6⅝	45	8½
14	6¾	45	9
14	6⅞	45	9⅜
14	7	45	9¾
14	7⅛	45	10⅛
14	7¼	45	10½
14	7⅜	45	10⅞
14	7½	45	11¼
14	7⅝	45	11⅝
14	7¾	46	0⅛
14	7⅞	46	0½
14	8	46	0⅞
14	8⅛	46	1¼
14	8¼	46	1⅝
14	8⅜	46	2
14	8½	46	2⅜
14	8⅝	46	2⅞
14	8¾	46	3¼
14	8⅞	46	3⅝
14	9	46	4
14	9⅛	46	4⅜
14	9¼	46	4⅞
14	9⅜	46	5¼

Diam. Ft.	Diam. In.	Circum. Ft.	Circum. In.
14	9½	46	5⅝
14	9⅝	46	6
14	9¾	46	6⅜
14	9⅞	46	6¾
14	10	46	7⅛
14	10⅛	46	7½
14	10¼	46	7⅞
14	10⅜	46	8⅜
14	10½	46	8¾
14	10⅝	46	9⅛
14	10¾	46	9½
14	10⅞	46	9⅞
14	11	46	10¼
14	11⅛	46	10⅝
14	11¼	46	11⅛
14	11⅜	46	11½
14	11½	46	11⅞
14	11⅝	47	0¼
14	11¾	47	0⅝
14	11⅞	47	1
15	0	47	1½
15	0⅛	47	1⅞
15	0¼	47	2¼
15	0⅜	47	2⅝
15	0½	47	3
15	0⅝	47	3⅜
15	0¾	47	3¾
15	0⅞	47	4⅛
15	1	47	4⅝
15	1⅛	47	5
15	1¼	47	5⅜
15	1⅜	47	5¾
15	1½	47	6⅛
15	1⅝	47	6½
15	1¾	47	6⅞

Diam. Ft.	Diam. In.	Circum. Ft.	Circum. In.
15	1⅞	47	7⅜
15	2	47	7¾
15	2⅛	47	8⅛
15	2¼	47	8½
15	2⅜	47	8⅞
15	2½	47	9¼
15	2⅝	47	9⅝
15	2¾	47	10⅛
15	2⅞	47	10½
15	3	47	10⅞
15	3⅛	47	11¼
15	3¼	47	11⅝
15	3⅜	48	0
15	3½	48	0⅜
15	3⅝	48	0⅞
15	3¾	48	1¼
15	3⅞	48	1⅝
15	4	48	2
15	4⅛	48	2⅜
15	4¼	48	2¾
15	4⅜	48	3⅛
15	4½	48	3½
15	4⅝	48	4
15	4¾	48	4⅜
15	4⅞	48	4¾
15	5	48	5⅛
15	5⅛	48	5½
15	5¼	48	5⅞
15	5⅜	48	6⅜
15	5½	48	6¾
15	5⅝	48	7⅛
15	5¾	48	7½
15	5⅞	48	7⅞
15	6	48	8¼

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Ft.
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Diam.	Circum.	
In.	Ft.	In.
½	49	10½
⅝	49	10⅞
¾	49	11¼
⅞	49	11⅝
	50	0
⅛	50	0½
¼	50	0⅞
⅜	50	1¼
½	50	1⅝
⅝	50	2
¾	50	2⅜
⅞	50	2¾
	50	3⅛
0⅛	50	3½
0¼	50	3⅞
0⅜	50	4¼
0½	50	4¾
0⅝	50	5⅛
0¾	50	5½
0⅞	50	5⅞
1	50	6¼
1⅛	50	6⅝
1¼	50	7
1⅜	50	7½
1½	50	7⅞
1⅝	50	8¼
1¾	50	8⅝
1⅞	50	9
2	50	9⅜
2⅛	50	9¾
2¼	50	10¼
2⅜	50	10⅝
2½	50	11
2⅝	50	11⅜
2¾	50	11¾

Diam.		Circum.	
Ft.	In.	Ft.	In.
16	2⅞	51	0⅛
16	3	51	0½
16	3⅛	51	1
16	3¼	51	1⅜
16	3⅜	51	1¾
16	3½	51	2⅛
16	3⅝	51	2½
16	3¾	51	2⅞
16	3⅞	51	3¼
16	4	51	3¾
16	4⅛	51	4⅛
16	4¼	51	4½
16	4⅜	51	4⅞
16	4½	51	5¼
16	4⅝	51	5⅝
16	4¾	51	6
16	4⅞	51	6½
16	5	51	6⅞
16	5⅛	51	7¼
16	5¼	51	7⅝
16	5⅜	51	8
16	5½	51	8⅜
16	5⅝	51	8¾
16	5¾	51	9¼
16	5⅞	51	9½
16	6	51	10
16	6⅛	51	10⅜
16	6¼	51	10¾
16	6⅜	51	11⅛
16	6½	51	11½
16	6⅝	52	0
16	6¾	52	0⅜
16	6⅞	52	0¾
16	7	52	1⅛

Diam.		Circum.	
Ft.	In.	Ft.	In.
16	7⅛	52	1½
16	7¼	52	1⅞
16	7⅜	52	2¼
16	7½	52	2⅝
16	7⅝	52	3⅛
16	7¾	52	3½
16	7⅞	52	3⅞
16	8	52	4¼
16	8⅛	52	4⅝
16	8¼	52	5
16	8⅜	52	5⅜
16	8½	52	5⅞
16	8⅝	52	6¼
16	8¾	52	6⅝
16	8⅞	52	7
16	9	52	7⅜
16	9⅛	52	7¾
16	9¼	52	8¼
16	9⅜	52	8⅝
16	9½	52	9
16	9⅝	52	9⅜
16	9¾	52	9¾
16	9⅞	52	10⅛
16	10	52	10½
16	10⅛	52	11
16	10¼	52	11⅜
16	10⅜	52	11¾
16	10½	53	0⅛
16	10⅝	53	0½
16	10¾	53	0⅞
16	10⅞	53	1¼
16	11	53	1⅝
16	11⅛	53	2
16	11¼	53	2½
16	11⅜	53	2⅞

Diam.		Circum.	
Ft.	In.	Ft.	In.
16	11½	53	3¼
16	11⅝	53	3⅝
16	11¾	53	4
16	11⅞	53	4½
17	0	53	4⅞
17	0⅛	53	5¼
17	0¼	53	5⅝
17	0⅜	53	6
17	0½	53	6⅜
17	0⅝	53	6¾
17	0¾	53	7¼
17	0⅞	53	7⅝
17	1	53	8
17	1⅛	53	8⅜
17	1¼	53	8¾
17	1⅜	53	9⅛
17	1½	53	9½
17	1⅝	53	10
17	1¾	53	10⅜
17	1⅞	53	10¾
17	2	53	11⅛
17	2⅛	53	11½
17	2¼	53	11⅞
17	2⅜	54	0¼
17	2½	54	0⅝
17	2⅝	54	1⅛
17	2¾	54	1½
17	2⅞	54	1⅞
17	3	54	2¼
17	3⅛	54	2⅝
17	3¼	54	3
17	3⅜	54	3½
17	3½	54	3⅞
17	3⅝	54	4¼
17	3¾	54	4⅝

Diam. Ft.	Diam. In.	Circum. Ft.	Circum. In.
17	3⅞	54	5
17	4	54	5⅜
17	4⅛	54	5¾
17	4¼	54	6⅛
17	4⅜	54	6⅝
17	4½	54	7
17	4⅝	54	7⅜
17	4¾	54	7¾
17	4⅞	54	8⅛
17	5	54	8½
17	5⅛	54	8⅞
17	5¼	54	9⅜
17	5⅜	54	9¾
17	5½	54	10⅛
17	5⅝	54	10½
17	5¾	54	10⅞
17	5⅞	54	11¼
17	6	54	11⅝
17	6⅛	55	0⅛
17	6¼	55	0½
17	6⅜	55	0⅞
17	6½	55	1¼
17	6⅝	55	1⅝
17	6¾	55	2
17	6⅞	55	2⅜
17	7	55	2⅞
17	7⅛	55	3¼
17	7¼	55	3⅝
17	7⅜	55	4
17	7½	55	4⅜
17	7⅝	55	4¾
17	7¾	55	5⅛
17	7⅞	55	5½
17	8	55	6

Diam. Ft.	Diam. In.	Circum. Ft.	Circum. In.
17	8⅛	55	6⅜
17	8¼	55	6¾
17	8⅜	55	7⅛
17	8½	55	7½
17	8⅝	55	7⅞
17	8¾	55	8⅜
17	8⅞	55	8¾
17	9	55	9⅛
17	9⅛	55	9½
17	9¼	55	9⅞
17	9⅜	55	10¼
17	9½	55	10⅝
17	9⅝	55	11⅛
17	9¾	55	11½
17	9⅞	55	11⅞
17	10	56	0¼
17	10⅛	56	0⅝
17	10¼	56	1
17	10⅜	56	1⅜
17	10½	56	1⅞
17	10⅝	56	2¼
17	10¾	56	2⅝
17	10⅞	56	3
17	11	56	3⅜
17	11⅛	56	3¾
17	11¼	56	4⅛
17	11⅜	56	4½
17	11½	56	5
17	11⅝	56	5⅜
17	11¾	56	5¾
17	11⅞	56	6⅛
18	0	56	6½
18	0⅛	56	6⅞
18	0¼	56	7¼
18	0⅜	56	7¾

Diam. Ft.	Diam. In.	Circum. Ft.	Circum. In.
18	0½	56	8⅛
18	0⅝	56	8½
18	0¾	56	8⅞
18	0⅞	56	9¼
18	1	56	9⅝
18	1⅛	56	10
18	1¼	56	10⅜
18	1⅜	56	10⅞
18	1½	56	11¼
18	1⅝	56	11⅝
18	1¾	57	0
18	1⅞	57	0⅜
18	2	57	0¾
18	2⅛	57	1¼
18	2¼	57	1⅝
18	2⅜	57	2
18	2½	57	2⅜
18	2⅝	57	2¾
18	2¾	57	3⅛
18	2⅞	57	3½
18	3	57	4
18	3⅛	57	4⅜
18	3¼	57	4¾
18	3⅜	57	5⅛
18	3½	57	5½
18	3⅝	57	5⅞
18	3¾	57	6⅜
18	3⅞	57	6¾
18	4	57	7⅛
18	4⅛	57	7½
18	4¼	57	7⅞
18	4⅜	57	8¼
18	4½	57	8⅝
18	4⅝	57	9
18	4¾	57	9½

Diam. Ft.	Diam. In
18	4[illegible]
18	5
18	5[illegible]
18	5[illegible]
18	5[illegible]
18	5[illegible]
18	5[illegible]
18	5[illegible]
18	5[illegible]
18	6
18	6[illegible]
18	6[illegible]
18	6[illegible]
18	6[illegible]
18	6[illegible]
18	6[illegible]
18	6[illegible]
18	7
18	7[illegible]
18	7[illegible]
18	7[illegible]
18	7[illegible]
18	7[illegible]
18	7[illegible]
18	7[illegible]
18	8
18	8[illegible]
18	8[illegible]
18	8[illegible]
18	8[illegible]
18	8[illegible]
18	8[illegible]
18	8[illegible]
18	9

Diam.	Circum.	Diam.	Circum.	Diam.	Circum.	Diam.	Circum.
Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.
18 9⅛	58 11¼	19 1⅛	59 11¾	19 5⅛	61 0⅜	19 9⅛	62 0⅞
18 9¼	58 11⅝	19 1¼	60 0⅛	19 5¼	61 0¾	19 9¼	62 1¼
18 9⅜	59 0	19 1⅜	60 0½	19 5⅜	61 1⅛	19 9⅜	62 1⅝
18 9½	59 0⅜	19 1½	60 1	19 5½	61 1½	19 9½	62 2⅛
18 9⅝	59 0¾	19 1⅝	60 1⅜	19 5⅝	61 1⅞	19 9⅝	62 2½
18 9¾	59 1⅛	19 1¾	60 1¾	19 5¾	61 2¼	19 9¾	62 2⅞
18 9⅞	59 1½	19 1⅞	60 2⅛	19 5⅞	61 2¾	19 9⅞	62 3¼
18 10	59 2	19 2	60 2½	19 6	61 3⅛	19 10	62 3⅝
18 10⅛	59 2⅜	19 2⅛	60 2⅞	19 6⅛	61 3½	19 10⅛	62 4
18 10¼	59 2¾	19 2¼	60 3¼	19 6¼	61 3⅞	19 10¼	62 4⅜
18 10⅜	59 3⅛	19 2⅜	60 3⅝	19 6⅜	61 4¼	19 10⅜	62 4⅞
18 10½	59 3½	19 2½	60 4⅛	19 6½	61 4⅝	19 10½	62 5¼
18 10⅝	59 3⅞	19 2⅝	60 4½	19 6⅝	61 5	19 10⅝	62 5⅝
18 10¾	59 4¼	19 2¾	60 4⅞	19 6¾	61 5½	19 10¾	62 6
18 10⅞	59 4¾	19 2⅞	60 5¼	19 6⅞	61 5⅞	19 10⅞	62 6⅜
18 11	59 5⅛	19 3	60 5⅝	19 7	61 6¼	19 11	62 6¾
18 11⅛	59 5½	19 3⅛	60 6	19 7⅛	61 6⅝	19 11⅛	62 7⅛
18 11¼	59 5⅞	19 3¼	60 6½	19 7¼	61 7	19 11¼	62 7½
18 11⅜	59 6¼	19 3⅜	60 6⅞	19 7⅜	61 7⅜	19•11⅜	62 8
18 11½	59 6⅝	19 3½	60 7¼	19 7½	61 7¾	19 11½	62 8⅜
18 11⅝	59 7	19 3⅝	60 7⅝	19 7⅝	61 8¼	19 11⅝	62 8¾
18 11¾	59 7½	19 3¾	60 8	19 7¾	61 8⅝	19 11¾	62 9⅛
18 11⅞	59 7⅞	19 3⅞	60 8⅜	19 7⅞	61 9	19 11⅞	62 9½
19 0	59 8¼	19 4	60 8¾	19 8	61 9⅜	20 0	62 9⅞
19 0⅛	59 8⅝	19 4⅛	60 9¼	19 8⅛	61 9¾	20 0⅛	62 10⅜
19 0¼	59 9	19 4¼	60 9⅝	19 8¼	61 10⅛	20 0¼	62 10¾
19 0⅜	59 9⅜	19 4⅜	60 10	19 8⅜	61 10½	20 0⅜	62 11⅛
19 0½	59 9¾	19 4½	60 10⅜	19 8½	61 11	20 0½	62 11½
19 0⅝	59 10¼	19 4⅝	60 10¾	19 8⅝	61 11⅜	20 0⅝	62 11⅞
19 0¾	59 10⅝	19 4¾	60 11⅛	19 8¾	61 11¾	20 0¾	63 0¼
19 0⅞	59 11	19 4⅞	60 11½	19 8⅞	62 0⅛	20 0⅞	63 0⅝
19 1	59 11⅜	19 5	60 11⅞	19 9	62 0½		

OBSERVATIONS ON TABLE I.

I do not intend to enter into any laboured argument to prove the general utility of these Tables, as their simplicity and clearness are sufficient to stamp their value to the artist and mechanic. It will be clearly perceived, on inspection, that the Table commences with as small a diameter as is generally used in hoops and rings, viz. one inch, and increases by the regular gradation of one-eighth of an inch, to upwards of twenty feet; and in the column marked Circumference, against each Diameter stand the respective circumferences: hence all that is necessary on inspecting these Tables is to enter into them with any proposed diameter or circumference, and an answer to the inquiry is immediately obtained.

Example.—Required the circumference of a circle, the diameter being 11 feet $7\frac{7}{8}$ inches.

In the column of circumferences, opposite the given diameter, stands 36 feet $7\frac{3}{8}$ inches, the circumference required.

But it will be necessary to observe, that in the formation of hoops and rings a contraction of the metal takes place. Now, the just allowance for this contraction is the exact thickness of the metal, which must be added to the diameter.

Ex. In making a hoop whose diameter inside is 6 feet $9\frac{1}{8}$ inches, the thickness of the iron being $\frac{1}{2}$ inch, this $\frac{1}{2}$ inch must be added to the given diameter, which will make it 6 feet $9\frac{5}{8}$ inches; this will allow $1\frac{5}{8}$ inch for the contraction in bending in a hoop of the above diameter, giving the circumference or length of iron required for the hoop, 21 feet $4\frac{3}{8}$ inches.

The foregoing example appertains to the formation of hoops or iron bent on the flat; but in the formation of rings or iron bent on the edge, the same rule must also be followed, only taking care to add the *breadth* instead of the thickness. As for example:

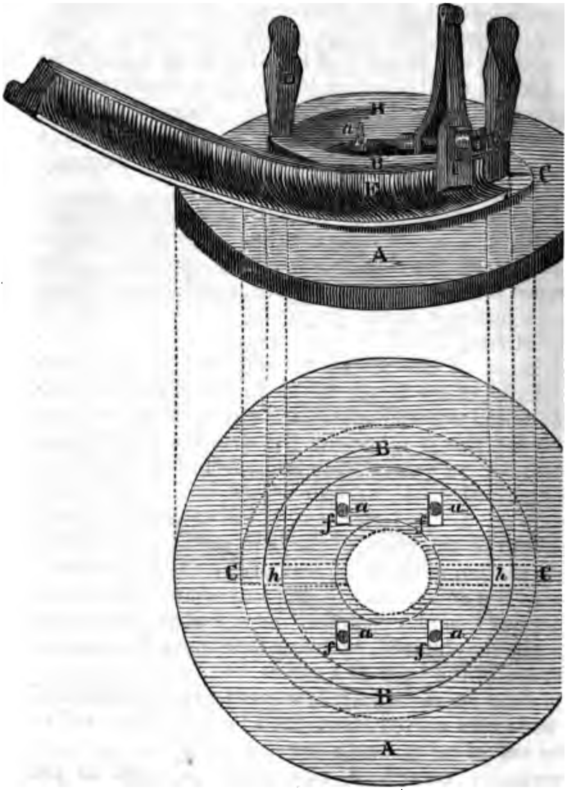
To make a ring whose inside diameter is 8 feet 2¼ inches, the *breadth* of the iron being 2½ inches; by adding the 2½ inches to the given diameter, will increase it to 8 feet 4¾ inches; opposite to this diameter in the column of circumferences stands 26 feet 4½ inches, being the length of iron necessary for the ring.

The foregoing observations relate more particularly to plain hoops and rings; but as respects the hoops that are on the wheels of railway carriages, a difference must be observed, which is as follows: These hoops having a flange projecting on the one edge of the surface, it will be necessary, in addition to the thickness of the metal, to add two-thirds of the thickness of the flange to the diameter, as the flange side would contract considerably more than the plain surface; this is supposing the tires are in a straight form, but, in general, they come from the iron-works in a curved state, as represented in the engraving, figure 3. In the latter case, it will be only necessary to add the thickness of the bare metal, as the aforesaid portion of the thickness of the flange is allowed for in the curve. By having had some experience in hoops of this nature, I have found that the curve may be exactly obtained, by using four times the circumference of the hoop as a radius.

In the engraving, fig. 1, is given a representation of a tire in its curved state, fixed to the blocks, and in the act of being bent; but if the tire has not been previously curved, it may easily be done in the

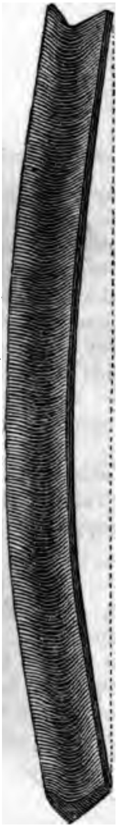
operation of bending: the smith must pay particul attention to this, or he will have his hoop bent in a angle.

Figures 1 and 2.



The following is a description of the figures 1 and 2: A is a strong cast-iron ground-plate, in which *ffff* are four slot-holes for the bolts *a a a a* to slide in, and are for the purpose of screwing down the two semicircular blocks, to prevent them from moving whilst the tire is in the act of being bent. B B is the block in two halves, opening at C C; the aperture is cut in a conical form, for the reception of the two conical wedges D D, on which the tire E is represented. *h h* are two holes in the ground-plate, into which the wedges are driven whilst blocking the hoop. F is a strong cramp for screwing the tire firm to the block whilst in the act of being bent round it: it is made with a joint at the top, and secures the tire to the block by means of a strong square-threaded screw, which screws into a boss on the innermost leg.

Figure 3.



But the practical utility of this Table is not confined to smiths alone; to the millwright it will be found equally useful and expeditious, as on a bare inspection of the Table he may ascertain the diameter of any wheel that may be required to be made, the pitch and number of teeth being given.

Ex. Suppose a wheel were ordered to be made to contain sixty teeth, the pitch of the teeth to be $3\frac{7}{8}$ inches, the dimensions of the wheel may be ascertained simply as follows:

Multiply the pitch of the tooth by the

number of teeth the wheel is to contain, and the product will be the circumference of the wheel: thus

	Inches.		
		$3\frac{7}{8}$	the pitch of the tooth,
		$10 \times 6 = 60$,	the number of teeth,
	3	$2\frac{3}{4}$	
		6	
Feet	19	$4\frac{1}{2}$	the circumference of the wheel.

However, by inspecting the column marked Circumference, I find the nearest number to this is 19 feet $4\frac{3}{8}$ inches, which is the eighth of an inch less than the true circumference; but if this $\frac{1}{8}$ were divided into sixty equal parts, it would not make the difference of a single hair's-breadth in the size of each tooth; so that it is sufficiently near for any practical purpose. The diameter answering to this circumference is 6 feet 2 inches; consequently, with one half of this number as a radius, the circumference of the wheel will be described.

The manner in which the foregoing Table of Circumferences is found is as follows: Taking the diameter at unity, we have by decimal proportion

$$\text{As } 1 : 3{\cdot}1416 :: \overset{\text{In.}}{1{\cdot}} : \overset{\text{In.}}{3{\cdot}1416},$$

and the decimal 1416 multiplied by 8, gives the circumference for 1 inch of diameter $3\frac{1}{8}$ inches.

In these Tables the number 3·1416 is divided by 8, which gives ·3927. This decimal proportion has been used as a constant, and the sum multiplied by 8 gives the excess above the decimal value in eighths of an inch.

EXAMPLE.

Diam.		In.	Circum.
1	....	3	1416 × 8 = ⅛·1328
			+ ·3927
1⅛	....	3	5343 × 8 = ½·2744
			+ ·3927
1¼	....	3	·9270 × 8 = ⅞·7160
			+ ·3927
1⅜	....	4	·3197 × 8 = ¼·6576
			+ ·3927
1½	....	4	·7124 × 8 = ⅝·6922
			+ ·3927
1⅝	....	5	·1051 × 8 = ·8408
			+ ·3927
1¾	....	5	·4978 × 8 = ⅜·9824
			+ ·3927
1⅞	....	5	·8905 × 8 = ⅞·1240
			+ ·3927
2	....	6	·2832 × 8 = ¼·2656

.—The nearest eighth of an inch is only given, as I
; it quite unnecessary to add the first decimal figure in
ble.

J. F.

TABLE II.*

SHOWING THE WEIGHT OF A LINEAL FOOT OF MALLEABLE RECTANGULAR OR FLAT IRON,

From an Eighth of an Inch to Three Inches thick; advancing by an Eighth and Quarter of an Inch in breadth.

Thick.	Broad.	lbs.	oz.	Thick.	Broad.	lbs.	oz.	Thick.	Broad.	lbs.	oz.
in.	in.			in.	in.			in.	in.		
$\frac{1}{8}$	$\frac{1}{4}$	0	1·6	$\frac{1}{8}$	$3\frac{7}{8}$	1	9·7	$\frac{1}{8}$	$7\frac{1}{2}$	3	1·8
	$\frac{3}{8}$	0	2·4		4	1	10·5		$7\frac{5}{8}$	3	2·6
	$\frac{1}{2}$	0	3·3		$4\frac{1}{8}$	1	11·3		$7\frac{3}{4}$	3	3·4
	$\frac{5}{8}$	0	4·1		$4\frac{1}{4}$	1	12·2		$7\frac{7}{8}$	3	4·3
	$\frac{3}{4}$	0	5·0		$4\frac{3}{8}$	1	13·0		8	3	5·1
	$\frac{7}{8}$	0	5·8		$4\frac{1}{2}$	1	13·8		$8\frac{1}{8}$	3	5·9
	1	0	6·6		$4\frac{5}{8}$	1	14·7		$8\frac{1}{4}$	3	6·7
	$1\frac{1}{8}$	0	7·5		$4\frac{3}{4}$	1	15·5		$8\frac{3}{8}$	3	7·6
	$1\frac{1}{4}$	0	8·3		$4\frac{7}{8}$	2	0·3		$8\frac{1}{2}$	3	8·4
	$1\frac{3}{8}$	0	9·1		5	2	1·2		$8\frac{5}{8}$	3	9·2
	$1\frac{1}{2}$	0	9·9		$5\frac{1}{8}$	2	2·0		$8\frac{3}{4}$	3	10·1
	$1\frac{5}{8}$	0	10·8		$5\frac{1}{4}$	2	2·8		$8\frac{7}{8}$	3	11·0
	$1\frac{3}{4}$	0	11·6		$5\frac{3}{8}$	2	3·7		9	3	11·7
	$1\frac{7}{8}$	0	12·4		$5\frac{1}{2}$	2	4·5		$9\frac{1}{8}$	3	12·6
	2	0	13·2		$5\frac{5}{8}$	2	5·3		$9\frac{1}{4}$	3	13·4
	$2\frac{1}{8}$	0	14·1		$5\frac{3}{4}$	2	6·1		$9\frac{3}{8}$	3	14·2
	$2\frac{1}{4}$	0	14·9		$5\frac{7}{8}$	2	7·0		$9\frac{1}{2}$	3	15·0
	$2\frac{3}{8}$	0	15·7		6	2	7·8		$9\frac{5}{8}$	3	15·9
	$2\frac{1}{2}$	1	0·6		$6\frac{1}{8}$	2	8·6		$9\frac{3}{4}$	4	0·7
	$2\frac{5}{8}$	1	1·4		$6\frac{1}{4}$	2	9·5		$9\frac{7}{8}$	4	1·5
	$2\frac{3}{4}$	1	2·2		$6\frac{3}{8}$	2	10·3		10	4	2·4
	$2\frac{7}{8}$	1	3·0		$6\frac{1}{2}$	2	11·1		$10\frac{1}{8}$	4	3·2
	3	1	3·9		$6\frac{5}{8}$	2	12·0		$10\frac{1}{4}$	4	4·0
	$3\frac{1}{8}$	1	4·7		$6\frac{3}{4}$	2	12·8		$10\frac{3}{8}$	4	4·9
	$3\frac{1}{4}$	1	5·5		$6\frac{7}{8}$	2	13·6		$10\frac{1}{2}$	4	5·7
	$3\frac{3}{8}$	1	6·4		7	2	14·4		$10\frac{5}{8}$	4	6·5
	$3\frac{1}{2}$	1	7·2		$7\frac{1}{8}$	2	15·3		$10\frac{3}{4}$	4	7·3
	$3\frac{5}{8}$	1	8·0		$7\frac{1}{4}$	3	0·1		$10\frac{7}{8}$	4	8·2
	$3\frac{3}{4}$	1	8·9		$7\frac{3}{8}$	3	1·0		11	4	9·0

* James Foden.

Thick.	Broad.	lbs.	oz.	Thick.	Broad.	lbs.	oz.	Thick.	Broad.	lbs.	oz.
in.	in.			in.	in.			in.	in.		
⅛	11⅛	4	9·8	¼	4	3	5·1	¼	8⅝	7	2·5
	11¼	4	10·7		4⅛	3	6·7		8¾	7	4·2
	11⅜	4	11·5		4¼	3	8·4		8⅞	7	5·8
	11½	4	12·3		4⅜	3	10·1		9	7	7·5
	11⅝	4	13·2		4½	3	11·7		9⅛	7	9·1
	11¾	4	14·0		4⅝	3	13·4		9¼	7	10·8
	11⅞	4	14·8		4¾	3	15·0		9⅜	7	12·5
	12	4	15·6		4⅞	4	0·7		9½	7	14·1
					5	4	2·4		9⅝	7	15·8
¼	½	0	6·6		5⅛	4	4·0		9¾	8	1·4
	⅝	0	8·3		5¼	4	5·7		9⅞	8	3·1
	¾	0	10·0		5⅜	4	7·3		10	8	4·8
	⅞	0	11·6		5½	4	9·0		10⅛	8	6·4
	1	0	13·2		5⅝	4	10·7		10¼	8	8·1
	1⅛	0	14·9		5¾	4	12·3		10⅜	8	9·7
	1¼	1	0·6		5⅞	4	14·0		10½	8	11·4
	1⅜	1	2·2		6	4	15·6		10⅝	8	13·1
	1½	1	3·9		6⅛	5	1·3		10¾	8	14·7
	1⅝	1	5·5		6¼	5	3·0		10⅞	9	0·4
	1¾	1	7·2		6⅜	5	4·6		11	9	2·0
	1⅞	1	9·0		6½	5	6·3		11⅛	9	3·7
	2	1	10·5		6⅝	5	7·9		11¼	9	5·4
	2⅛	1	12·2		6¾	5	9·6		11⅜	9	7·0
	2¼	1	13·8		6⅞	5	11·3		11½	9	8·7
	2⅜	1	15·5		7	5	13·0		11⅝	9	10·3
	2½	2	1·2		7⅛	5	14·6		11¾	9	12·0
	2⅝	2	2·8		7¼	6	0·2		11⅞	9	13·7
	2¾	2	4·5		7⅜	6	2·0		12	9	15·3
	2⅞	2	6·1		7½	6	3·6				
	3	2	7·8		7⅝	6	5·2	⅜	¾	0	14·9
	3⅛	2	9·5		7¾	6	7·0		⅞	1	1·3
	3¼	2	11·1		7⅞	6	8·5		1	1	3·8
	3⅜	2	12·8		8	6	10·2		1⅛	1	6·3
	3½	2	14·4		8⅛	6	12·0		1¼	1	8·8
	3⅝	3	0·1		8¼	6	13·5		1⅜	1	11·3
	3¾	3	1·8		8⅜	6	15·2		1½	1	13·8
	3⅞	3	3·4		8½	7	0·8		1⅝	2	0·3

Thick.	Broad.	lbs.	oz.	Thick.	Broad.	lbs.	oz.	Thick.	Broad.	lbs.	oz.
in.	in.			in.	in.			in.	in.		
⅜	1¾	2	2·7	⅜	6⅜	7	14·6	⅜	11	13	10·5
	1⅞	2	5·2		6½	8	1·1		11⅛	13	13·0
	2	2	7·7		6⅝	8	3·6		11¼	13	15·5
	2⅛	2	10·2		6¾	8	6·1		11⅜	14	2·0
	2¼	2	12·7		6⅞	8	8·6		11½	14	4·5
	2⅜	2	15·1		7	8	11·1		11⅝	14	7·0
	2½	3	1·6		7⅛	8	13·5		11¾	14	9·4
	2⅝	3	4·1		7¼	9	0·0		11⅞	14	11·9
	2¾	3	6·6		7⅜	9	2·5		12	14	14·4
	2⅞	3	9·1		7½	9	5·0	½	1	1	10·4
	3	3	11·6		7⅝	9	7·5		1⅛	1	13·8
	3⅛	3	14·1		7¾	9	10·0		1¼	2	1·1
	3¼	4	0·5		7⅞	9	12·4		1⅜	2	4·4
	3⅜	4	3·0		8	9	14·9		1½	2	7·7
	3½	4	5·5		8⅛	10	1·4		1⅝	2	11·0
	3⅝	4	8·0		8¼	10	3·9		1¾	2	14·3
	3¾	4	10·5		8⅜	10	6·4		1⅞	3	1·6
	3⅞	4	13·0		8½	10	8·9		2	3	4·9
	4	4	15·4		8⅝	10	11·3		2⅛	3	8·3
	4⅛	5	1·9		8¾	10	13·8		2¼	3	11·6
	4¼	5	4·4		8⅞	11	0·3		2⅜	3	14·9
	4⅜	5	6·9		9	11	2·8		2½	4	2·2
	4½	5	9·4		9⅛	11	5·3		2⅝	4	5·5
	4⅝	5	11·9		9¼	11	7·8		2¾	4	8·8
	4¾	5	14·3		9⅜	11	10·3		2⅞	4	12·1
	4⅞	6	0·8		9½	11	12·7		3	4	15·4
	5	6	3·3		9⅝	11	15·2		3⅛	5	2·8
	5⅛	6	5·8		9¾	12	1·7		3¼	5	6·1
	5¼	6	8·3		9⅞	12	4·2		3⅜	5	9·4
	5⅜	6	10·8		10	12	6·7		3½	5	12·7
	5½	6	13·2		10⅛	12	9·2		3⅝	6	0·0
	5⅝	6	15·7		10¼	12	11·6		3¾	6	3·3
	5¾	7	2·2		10⅜	12	14·1		3⅞	6	6·6
	5⅞	7	4·7		10½	13	0·6		4	6	9·9
	6	7	7·2		10⅝	13	3·1		4⅛	6	13·3
	6⅛	7	9·7		10¾	13	5·6		4¼	7	0·6
	6¼	7	12·2		10⅞	13	8·1				

Thick.	Broad.	lbs.	oz.	Thick.	Broad.	lbs.	oz.	Thick.	Broad.	lbs.	oz.
in.	in.			in.	in.			in.	in.		
½	4⅜	7	3·9	½	9	14	14·4	⅝	2⅝	5	6·9
	4½	7	7·2		9⅛	15	1·7		2¾	5	11·0
	4⅝	7	10·5		9¼	15	5·0		2⅞	5	15·2
	4¾	7	13·8		9⅜	15	8·4		3	6	3·3
	4⅞	8	1·1		9½	15	11·7		3⅛	6	7·5
	5	8	4·4		9⅝	15	15·0		3¼	6	11·6
	5⅛	8	7·7		9¾	16	2·3		3⅜	6	15·7
	5¼	8	11·1		9⅞	16	5·6		3½	7	3·9
	5⅜	8	14·4		10	16	8·9		3⅝	7	8·0
	5½	9	1·7		10⅛	16	12·2		3¾	7	12·2
	5⅝	9	5·0		10¼	16	15·5		3⅞	8	0·3
	5¾	9	8·3		10⅜	17	2·8		4	8	4·4
	5⅞	9	11·6		10½	17	6·2		4⅛	8	8·6
	6	9	14·9		10⅝	17	9·5		4¼	8	12·7
	6⅛	10	2·2		10¾	17	12·8		4⅜	9	0·9
	6¼	10	5·6		10⅞	18	0·1		4½	9	5·0
	6⅜	10	8·9		11	18	3·4		4⅝	9	9·1
	6½	10	12·2		11⅛	18	6·7		4¾	9	13·3
	6⅝	10	15·5		11¼	18	10·0		4⅞	10	1·4
	6¾	11	2·8		11⅜	18	13·3		5	10	5·6
	6⅞	11	6·1		11½	19	0·7		5⅛	10	9·7
	7	11	9·4		11⅝	19	4·0		5¼	10	13·8
	7⅛	11	12·7		11¾	19	7·3		5⅜	11	2·0
	7¼	12	0·0		11⅞	19	10·6		5½	11	6·1
	7⅜	12	3·4		12	19	13·9		5⅝	11	10·3
	7½	12	6·7						5¾	11	14·4
	7⅝	12	10·0	⅝	1¼	2	9·4		5⅞	12	2·5
	7¾	12	13·3		1⅜	2	13·5		6	12	6·7
	7⅞	13	0·6		1½	3	1·6		6⅛	12	10·8
	8	13	3·9		1⅝	3	5·8		6¼	12	15·0
	8⅛	13	7·2		1¾	3	9·9		6⅜	13	3·1
	8¼	13	10·5		1⅞	3	14·1		6½	13	7·2
	8⅜	13	13·9		2	4	2·2		6⅝	13	11·4
	8½	14	1·2		2⅛	4	6·3		6¾	13	15·5
	8⅝	14	4·5		2¼	4	10·5		6⅞	14	3·7
	8¾	14	7·8		2⅜	4	14·6		7	14	7·8
	8⅞	14	11·1		2½	5	2·8		7⅛	14	11·9

Thick.	Broad.	lbs.	oz.	Thick.	Broad.	lbs.	oz.	Thick.	Broad.	lbs.	oz.
in.	in.			in.	in.			in.	in.		
⅝	7¼	15	0·1	⅝	11⅞	24	9·3	¾	5¾	14	4·5
	7⅜	15	4·2		12	24	13·4		5⅞	14	9·5
	7½	15	8·4						6	14	14·4
	7⅝	15	12·5	¾	1½	3	11·6		6⅛	15	3·4
	7¾	16	0·6		1⅝	4	0·5		6¼	15	8·4
	7⅞	16	4·8		1¾	4	5·5		6⅜	15	13·3
	8	16	8·9		1⅞	4	10·5		6½	16	2·3
	8⅛	16	13·1		2	4	15·4		6⅝	16	7·3
	8¼	17	1·2		2⅛	5	4·4		6¾	16	12·2
	8⅜	17	5·3		2¼	5	9·4		6⅞	17	1·2
	8½	17	9·5		2⅜	5	14·3		7	17	6·2
	8⅝	17	13·6		2½	6	3·3		7⅛	17	11·1
	8¾	18	1·8		2⅝	6	8·3		7¼	18	0·1
	8⅞	18	5·9		2¾	6	13·2		7⅜	18	5·1
	9	18	10·0		2⅞	7	2·2		7½	18	10·0
	9⅛	18	14·2		3	7	7·2		7⅝	18	15·0
	9¼	19	2·3		3⅛	7	12·2		7¾	19	4·0
	9⅜	19	6·5		3¼	8	1·1		7⅞	19	8·9
	9½	19	10·6		3⅜	8	6·1		8	19	13·9
	9⅝	19	14·7		3½	8	11·1		8⅛	20	2·9
	9¾	20	2·9		3⅝	9	0·0		8¼	20	7·8
	9⅞	20	7·0		3¾	9	5·0		8⅜	20	12·8
	10	20	11·2		3⅞	9	10·0		8½	21	1·8
	10⅛	20	15·3		4	9	14·9		8⅝	21	6·7
	10¼	21	3·4		4⅛	10	3·9		8¾	21	11·7
	10⅜	21	7·6		4¼	10	8·9		8⅞	22	0·7
	10½	21	11·7		4⅜	10	13·8		9	22	5·7
	10⅝	21	15·9		4½	11	2·8		9⅛	22	10·6
	10¾	22	4·0		4⅝	11	7·8		9¼	22	15·6
	10⅞	22	8·1		4¾	11	12·7		9⅜	23	4·6
	11	22	12·3		4⅞	12	1·7		9½	23	9·5
	11⅛	23	0·4		5	12	6·7		9⅝	23	14·5
	11¼	23	4·6		5⅛	12	11·6		9¾	24	3·5
	11⅜	23	8·7		5¼	13	0·6		9⅞	24	8·4
	11½	23	12·8		5⅜	13	5·6		10	24	13·4
	11⅝	24	1·0		5½	13	10·6		10⅛	25	2·4
	11¾	24	5·1		5⅝	13	15·5		10¼	25	7·3

rs.	lbs.	oz.	Thick.	Broad.	lbs.	oz.	Thick.	Broad.	qrs.	lbs.	oz.
			in.	in.			in.	in.			
0	25	12·3	⅞	4½	13	0·6	⅞	9⅛	0	26	7·1
0	26	1·3		4⅝	13	6·4		9¼	0	26	12·9
0	26	6·2		4¾	13	12·2		9⅜	0	27	2·7
0	26	11·2		4⅞	14	2·0		9½	0	27	8·5
0	27	0·2		5	14	7·8		9⅝	0	27	14·3
0	27	5·1		5⅛	14	13·6		9¾	1	0	4·0
0	27	10·1		5¼	15	3·4		9⅞	1	0	9·8
0	27	15·1		5⅜	15	9·2		10	1	0	15·6
1	0	4·0		5½	15	15·0		10⅛	1	1	5·4
1	0	9·0		5⅝	16	4·8		10¼	1	1	11·2
1	0	14·0		5¾	16	10·6		10⅜	1	2	1·0
1	1	3·0		5⅞	17	0·4		10½	1	2	6·8
1	1	7·9		6	17	6·2		10⅝	1	2	12·6
1	1	12·9		6⅛	17	12·0		10¾	1	3	2·4
				6¼	18	1·8		10⅞	1	3	8·2
0	5	1·1		6⅜	18	7·6		11	1	3	14·0
0	5	6·9		6½	18	13·4		11⅛	1	4	3·8
0	5	12·7		6⅝	19	3·1		11¼	1	4	9·6
0	6	2·5		6¾	19	8·9		11⅜	1	4	15·4
0	6	8·3		6⅞	19	14·7		11½	1	5	5·2
0	6	14·1		7	20	4·5		11⅝	1	5	11·0
0	7	3·9		7⅛	20	10·3		11¾	1	6	0·8
0	7	9·7		7¼	21	0·1		11⅞	1	6	6·6
0	7	15·5		7⅜	21	5·9		12	1	6	12·4
0	8	5·3		7½	21	11·7					
0	8	11·1		7⅝	22	1·5	1	2	0	6	10·0
0	9	0·9		7¾	22	7·3		2⅛	0	7	0·6
0	9	6·7		7⅞	22	13·1		2¼	0	7	7·2
0	9	12·4		8	23	2·9		2⅜	0	7	13·8
0	10	2·2		8⅛	23	8·7		2½	0	8	4·4
0	10	8·0		8¼	23	14·5		2⅝	0	8	11·1
0	10	13·8		8⅜	24	4·3		2¾	0	9	1·7
0	11	3·6		8½	24	10·1		2⅞	0	9	8·3
0	11	9·4		8⅝	24	15·9		3	0	9	14·7
0	11	15·2		8¾	25	5·7		3⅛	0	10	5·6
0	12	5·0		8⅞	25	11·5		3¼	0	10	12·2
0	12	10·8		9	26	1·3		3⅜	0	11	2·8

Thick.	Broad.	lbs.	oz.	Thick.	Broad.	qrs.	lbs.	oz.	Thick.	Broad.	qrs.	lb
in.	in.			in.	in.				in.	in.		
1	3½	11	9·4	1	6⅜	0	21	1·8	1	9¼	1	[illegible]
	3⅝	12	0·1		6½	0	21	8·4		9⅜	1	[illegible]
	3¾	12	6·7		6⅝	0	21	15·0		9½	1	[illegible]
	3⅞	12	13·3		6¾	0	22	5·7		9⅝	1	[illegible]
	4	13	3·9		6⅞	0	22	12·3		9¾	1	4
	4⅛	13	10·6		7	0	23	2·9		9⅞	1	4
	4¼	14	1·2		7⅛	0	23	9·5		10	1	[illegible]
	4⅜	14	7·8		7¼	0	24	0·2		10⅛	1	[illegible]
	4½	14	14·4		7⅜	0	24	6·6		10¼	1	[illegible]
	4⅝	15	5·0		7½	0	24	13·4		10⅜	1	6
	4¾	15	11·7		7⅝	0	25	4·0		10½	1	6
	4⅞	16	2·3		7¾	0	25	10·6		10⅝	1	7
	5	16	8·9		7⅞	0	26	1·3		10¾	1	7
	5⅛	16	15·5		8	0	26	7·9		10⅞	1	8
	5¼	17	6·2		8⅛	0	26	14·5		11	1	8
	5⅜	17	12·8		8¼	0	27	5·1		11⅛	1	8
	5½	18	3·4		8⅜	0	27	11·8		11¼	1	9
	5⅝	18	10·0		8½	1	0	2·4		11⅜	1	9
	5¾	19	0·7		8⅝	1	0	9·0		11½	1	10
	5⅞	19	7·3		8¾	1	0	15·6		11⅝	1	10
	6	19	13·9		8⅞	1	1	6·3		11¾	1	10
	6⅛	20	4·5		9	1	1	12·9		11⅞	1	11
	6¼	20	11·2		9⅛	1	2	3·5		12	1	11

Thick.	Broad.	qrs.	lbs.	oz.	Thick.	Broad.	qrs.	lbs.	oz.	Thick.	Broad.	qrs.	lbs.	oz.
in.	in.				in.	in.				in.	in.			
1⅛	2¼	0	8	6·1	1⅛	11½	1	14	13·5	1¼	10¾	1	16	8·0
	2½	0	9	5·0		11¾	1	15	12·4		11	1	17	8·6
	2¾	0	10	3·9		12	1	16	11·4		11¼	1	18	9·2
	3	0	11	2·8							11½	1	19	9·7
	3¼	0	12	1·7	1¼	2½	0	10	5·6		11¾	1	20	10·3
	3½	0	13	0·6		2¾	0	11	6·1		12	1	21	10·8
	3¾	0	13	15·5		3	0	12	6·7					
	4	0	14	14·4		3¼	0	13	7·2	1⅜	2¾	0	12	8·3
	4¼	0	15	13·3		3½	0	14	7·8		3	0	13	10·6
	4½	0	16	12·2		3¾	0	15	8·4		3¼	0	14	12·8
	4¾	0	17	11·1		4	0	16	8·9		3½	0	15	15·0
	5	0	18	10·0		4¼	0	17	9·5		3¾	0	17	1·2
	5¼	0	19	8·9		4½	0	18	10·0		4	0	18	3·4
	5½	0	20	7·8		4¾	0	19	10·6		4¼	0	19	5·6
	5¾	0	21	6·8		5	0	20	11·2		4½	0	20	7·8
	6	0	22	5·7		5¼	0	21	11·7		4¾	0	21	10·1
	6¼	0	23	4·6		5½	0	22	12·3		5	0	22	12·3
	6½	0	24	3·5		5¾	0	23	12·8		5¼	0	23	14·5
	6¾	0	25	2·4		6	0	24	13·4		5½	0	25	0·7
	7	0	26	1·3		6¼	0	25	14·0		5¾	0	26	2·9
	7¼	0	27	0·2		6½	0	26	14·5		6	0	27	5·1
	7½	0	27	15·1		6¾	0	27	15·1		6¼	1	0	7·4
	7¾	1	0	14·0		7	1	0	15·6		6½	1	1	9·6
	8	1	1	12·9		7¼	1	2	0·2		6¾	1	2	11·8
	8¼	1	2	11·8		7½	1	3	0·8		7	1	3	14·0
	8½	1	3	10·7		7¾	1	4	1·3		7¼	1	5	0·2
	8¾	1	4	9·6		8	1	5	1·9		7½	1	6	2·4
	9	1	5	8·5		8¼	1	6	2·4		7¾	1	7	4·7
	9¼	1	6	7·4		8½	1	7	3·0		8	1	8	6·9
	9½	1	7	6·3		8¾	1	8	3·6		8¼	1	9	9·1
	9¾	1	8	5·2		9	1	9	4·1		8½	1	10	11·3
	10	1	9	4·1		9¼	1	10	4·7		8¾	1	11	13·5
	10¼	1	10	3·0		9½	1	11	5·2		9	1	12	15·7
	10½	1	11	1·9		9¾	1	12	5·8		9¼	1	14	2·0
	10¾	1	12	0·8		10	1	13	6·4		9½	1	15	4·2
	11	1	12	15·7		10¼	1	14	6·9		9¾	1	16	6·4
	11¼	1	13	14·6		10½	1	15	7·5		10	1	17	8·6

Thick.	Broad.	qrs.	lbs.	oz.
in.	in.			
1⅜	10¼	1	18	10·8
	10½	1	19	13·0
	10¾	1	20	15·2
	11	1	22	1·5
	11¼	1	23	3·7
	11½	1	24	5·9
	11¾	1	25	8·1
	12	1	26	10·3
1½	3	0	14	14·4
	3¼	0	16	2·3
	3½	0	17	6·2
	3¾	0	18	10·0
	4	0	19	13·9
	4¼	0	21	1·8
	4½	0	22	5·7
	4¾	0	23	9·5
	5	0	24	13·4
	5¼	0	26	1·3
	5½	0	27	5·1
	5¾	1	0	9·0
	6	1	1	12·9
	6¼	1	3	0·8
	6½	1	4	4·6
	6¾	1	5	8·5
	7	1	6	12·4
	7¼	1	8	0·2
	7½	1	9	4·1
	7¾	1	10	8·0
	8	1	11	11·9
	8¼	1	12	15·7
	8½	1	14	3·6
	8¾	1	15	7·5
	9	1	16	11·4
	9¼	1	17	15·2
	9½	1	19	3·1
	9¾	1	20	7·0

Thick.	Broad.	qrs.	lbs.	oz.
in.	in.			
1½	10	1	21	10·8
	10¼	1	22	14·7
	10½	1	24	2·6
	10¾	1	25	6·5
	11	1	26	10·3
	11¼	1	27	14·2
	11½	2	1	2·1
	11¾	2	2	5·9
	12	2	3	9·8
1⅝	3¼	0	17	7·8
	3½	0	18	13·4
	3¾	0	20	2·9
	4	0	21	8·4
	4¼	0	22	13·9
	4½	0	24	3·5
	4¾	0	25	9·0
	5	0	26	14·5
	5¼	1	0	4·0
	5½	1	1	9·6
	5¾	1	2	15·1
	6	1	4	4·6
	6¼	1	5	10·2
	6½	1	6	15·7
	6¾	1	8	5·2
	7	1	9	10·7
	7¼	1	11	0·3
	7½	1	12	5·8
	7¾	1	13	11·3
	8	1	15	0·9
	8¼	1	16	6·4
	8½	1	17	11·9
	8¾	1	19	1·4
	9	1	20	7·0
	9¼	1	21	12·5
	9½	1	23	2·0
	9¾	1	24	7·6

Thick.	Broad.	qrs
in.	in.	
1⅝	10	1
	10¼	1
	10½	2
	10¾	2
	11	2
	11¼	2
	11½	2
	11¾	2
	12	2
1¾	3½	0
	3¾	0
	4	0
	4¼	0
	4½	0
	4¾	0
	5	1
	5¼	1
	5½	1
	5¾	1
	6	1
	6¼	1
	6½	1
	6¾	1
	7	1
	7¼	1
	7½	1
	7¾	1
	8	1
	8¼	1
	8½	1
	8¾	1
	9	1
	9¼	1
	9½	1
	9¾	2
	10	2

Thick.	Broad.	qrs.	lbs.	oz.	Thick.	Broad.	qrs.	lbs.	oz.	Thick.	Broad.	qrs.	lbs.	oz.
in.	in.				in.	in.				in.	in.			
1¾	10¼	2	3	6·5	1⅞	10¾	2	10	12·1	2	11½	2	20	2·8
	10½	2	4	13·7		11	2	12	4·9		11¾	2	21	13·3
	10¾	2	6	4·9		11¼	2	13	13·8		12	2	23	7·8
	11	2	7	12·1		11½	2	15	6·6					
	11¼	2	9	3·2		11¾	2	16	15·4	2⅛	4¼	1	1	14·5
	11½	2	10	10·4		12	2	18	8·3		4½	1	3	10·7
	11¾	2	12	1·6							4¾	1	5	6·8
	12	2	13	8·8	2	4	0	26	7·9		5	1	7	3·0
						4¼	1	0	2·4		5¼	1	8	15·2
1⅞	3¾	0	23	4·6		4½	1	1	12·9		5½	1	10	11·3
	4	0	24	13·4		4¾	1	3	7·4		5¾	1	12	7·5
	4¼	0	26	6·2		5	1	5	1·9		6	1	14	3·6
	4½	0	27	15·1		5¼	1	6	12·4		6¼	1	15	15·8
	4¾	1	1	7·9		5½	1	8	6·9		6½	1	17	11·9
	5	1	3	0·8		5¾	1	10	1·4		6¾	1	19	8·1
	5¼	1	4	9·6		6	1	11	11·9		7	1	21	4·2
	5½	1	6	2·4		6¼	1	13	6·4		7¼	1	23	0·4
	5¾	1	7	11·3		6½	1	15	0·9		7½	1	24	12·5
	6	1	9	4·6		6¾	1	16	11·4		7¾	1	26	8·7
	6¼	1	10	13·0		7	1	18	5·8		8	2	0	4·8
	6½	1	12	5·8		7¼	1	20	0·3		8¼	2	2	1·0
	6¾	1	13	14·6		7½	1	21	10·8		8½	2	3	13·1
	7	1	15	7·5		7¾	1	23	5·3		8¾	2	5	9·3
	7¼	1	17	0·3		8	1	24	15·8		9	2	7	5·4
	7½	1	18	9·2		8¼	1	26	10·3		9¼	2	9	1·6
	7¾	1	20	2·0		8½	2	0	4·8		9½	2	10	13·7
	8	1	21	10·8		8¾	2	1	15·3		9¾	2	12	9·9
	8¼	1	23	3·7		9	2	3	9·0		10	2	14	6·0
	8½	1	24	12·5		9¼	2	5	4·3		10¼	2	16	2·2
	8¾	1	26	5·4		9½	2	6	14·8		10½	2	17	14·3
	9	1	27	14·2		9¾	2	8	9·3		10¾	2	19	10·5
	9¼	2	1	7·0		10	2	10	3·8		11	2	21	6·6
	9½	2	2	15·9		10¼	2	11	14·3		11¼	2	23	2·8
	9¾	2	4	8·7		10½	2	13	8·8		11½	2	24	15·0
	10	2	6	1·6		10¾	2	15	3·3		11¾	2	26	11·1
	10¼	2	7	10·4		11	2	16	13·8		12	3	0	7·3
	10½	2	9	3·2		11¼	2	18	8·3					

Thick.	Broad.	qrs.	lbs.	oz.	Thick.	Broad.	qrs.	lbs.	oz.	Thick.	Broad.	qrs.	l
in.	in.				in.	in.				in.	in.		
2¼	4½	1	5	8·5	2⅜	6	1	19	3·1	2½	7¾	2	
	4¾	1	7	6·3		6¼	1	21	2·6		8	2	1
	5	1	9	4·1		6½	1	23	2·0		8¼	2	1
	5¼	1	11	1·9		6¾	1	25	1·5		8½	2	1
	5½	1	12	15·7		7	1	27	1·0		8¾	2	1
	5¾	1	14	13·5		7¼	2	1	0·4		9	2	1
	6	1	16	11·4		7½	2	2	15·9		9¼	2	2
	6¼	1	18	9·2		7¾	2	4	15·3		9½	2	2
	6½	1	20	7·0		8	2	6	14·8		9¾	2	2
	6¾	1	22	4·8		8¼	2	8	14·3		10	2	2
	7	1	24	2·6		8½	2	10	13·7		10¼	3	
	7¼	1	26	0·4		8¾	2	12	13·2		10½	3	
	7½	1	27	14·2		9	2	14	12·7		10¾	3	
	7¾	2	1	12·0		9¼	2	16	12·1		11	3	
	8	2	3	9·8		9½	2	18	11·6		11¼	3	
	8¼	2	5	7·6		9¾	2	20	11·1		11½	3	1
	8½	2	7	5·4		10	2	22	10·5		11¾	3	1
	8¾	2	9	3·2		10¼	2	24	10·0		12	3	1
	9	2	11	1·0		10½	2	26	9·4	2⅝	5¼	1	1
	9¼	2	12	14·9		10¾	3	0	8·9		5½	1	1
	9½	2	14	12·7		11	3	2	8·4		5¾	1	2
	9¾	2	16	10·5		11¼	3	4	7·8		6	1	2
	10	2	18	8·3		11½	3	6	7·3		6¼	1	2
	10¼	2	20	6·1		11¾	3	8	6·8		6½	2	
	10½	2	22	3·9		12	3	10	6·2		6¾	2	
	10¾	2	24	1·7	2½	5	1	13	6·4		7	2	
	11	2	25	15·5		5¼	1	15	7·5		7¼	2	
	11¼	2	27	13·3		5½	1	17	8·6		7½	2	
	11½	3	1	11·1		5¾	1	19	9·7		7¾	2	1
	11¾	3	3	8·9		6	1	21	10·8		8	2	1
	12	3	5	6·7		6¼	1	23	12·0		8¼	2	1
2⅜	4¾	1	9	5·8		6½	1	25	13·1		8½	2	1
	5	1	11	5·2		6¾	1	27	14·2		8¾	2	2
	5¼	1	13	4·7		7	2	1	15·3		9	2	2
	5½	1	15	4·2		7¼	2	4	0·4		9¼	2	2
	5¾	1	17	3·6		7½	2	6	1·6		9½	2	2

rs.	lbs.	oz.	Thick.	Broad.	qrs.	lbs.	oz.	Thick.	Broad.	qrs.	lbs.	oz.
			in.	in.				in.	in.			
3	0	12·2	2¾	10½	3	11	10·1	2⅞	11¼	3	23	1·9
3	2	15·0		10¾	3	13	14·5		11½	3	25	8·0
3	5	1·8		11	3	16	3·0		11¾	3	27	14·1
3	7	4·6		11¼	3	18	7·4		12	4	2	4·2
3	9	7·3		11½	3	20	11·8					
3	11	10·1		11¾	3	23	0·3	3	6	2	3	9·8
3	13	12·9		12	3	25	4·7		6¼	2	6	1·6
3	15	15·7							6½	2	8	9·3
3	18	2·4	2⅞	5¾	1	26	12·0		6¾	2	11	1·0
3	20	5·2		6	2	1	2·1		7	2	13	8·8
				6¼	2	3	8·2		7¼	2	16	0·5
1	22	1·5		6½	2	5	14·2		7½	2	18	8·3
1	24	5·9		6¾	2	8	4·3		7¾	2	21	0·0
1	26	10·3		7	2	10	10·4		8	2	23	7·8
2	0	14·8		7¼	2	13	0·5		8¼	2	25	15·5
2	3	3·2		7½	2	15	6·6		8½	3	0	7·3
2	5	7·6		7¾	2	17	12·7		8¾	3	2	15·0
2	7	12·1		8	2	20	2·8		9	3	5	6·7
2	10	0·5		8¼	2	22	8·9		9¼	3	7	14·5
2	12	4·9		8½	2	24	15·0		9½	3	10	6·2
2	14	9·4		8¾	2	27	5·0		9¾	3	12	14·0
2	16	13·8		9	3	1	11·1		10	3	15	5·7
2	19	2·2		9¼	3	4	1·2		10¼	3	17	13·5
2	21	6·6		9½	3	6	7·3		10½	3	20	5·2
2	23	11·1		9¾	3	8	13·4		10¾	3	22	13·0
2	25	15·5		10	3	11	3·5		11	3	25	4·7
3	0	3·9		10¼	3	13	9·6		11¼	3	27	12·4
3	2	8·4		10½	3	15	15·7		11½	4	2	4·2
3	4	12·8		10¾	3	18	5·7		11¾	4	4	11·9
3	7	1·2		11	3	20	11·8		12	4	7	3·7
3	9	5·7										

The weights here given are in pounds, ounces, a decimal parts, avoirdupois; and it will be seen, inspecting the Table, that the first numbers in e page are those which apply to nut iron, and that breadth increases by $\frac{1}{8}$th of an inch as far page 86, after which they rise by $\frac{1}{4}$th of an inch breadth to the end. The last numbers in each p show the weight of a square foot, according to respective thickness of each bar. Hence the wei of any length of a bar of rectangular iron may ascertained simply, as follows:

Rule.—Multiply the tabular weight, according the thickness and breadth, by the number of feet the bar, the product will be the weight required.

Example.—In a bar of iron whose thickness is inches, the breadth $6\frac{3}{4}$ inches, and the length 18 f what is the weight thereof?

In the Table for $2\frac{5}{8}$ inches thick, and opposite inches, stand 2 qrs. 2 lbs. 10·9 oz., being the wei of one lineal foot. Multiply this number by 18 f and we have as follows:

cwt.	qrs.	lbs.	oz.	
0	2	2	10·9	
			6 × 3 = 18	
3	0	16	1·4	
			3	
9	1	20	4·2	Answer.

The foregoing Table of weights is obtained by t following approximate rule:

Multiply the area of the end of the bar by t length of one foot, and multiply that product by 3·3 the product will be the weight in pounds avoirdupo nearly.*

* By this rule the weight of any length of malleable rect*gular iron* may be ascertained nearly.

—Required the weight of one lineal foot of
ble iron, $\frac{1}{8}$ inch thick, and $2\frac{1}{4}$ inches broad.

$= 1{\cdot}125 \times 1 \times 1{\cdot}125 \times 3{\cdot}32 = 3{\cdot}735$ lbs. or 3 lbs. 11·76 oz.

r the sake of expedition these Tables have been
icted as follows. Having found, by the above
e weight of one lineal foot for $\frac{1}{8}$th of an inch
ng to the thickness, it has been constantly
until the breadth has attained to one foot.

Example.

, then
$\cdot 25 = {\cdot}015625 \times 3{\cdot}32 = {\cdot}05187500$ lbs. $\times 16 = {\cdot}83$ oz.

Here ·83
+ ·83

Ounce 1·66 = $\frac{1}{4}$ inch broad.
+ ·83

2·49 = $\frac{3}{8}$
+ ·83

3·32 = $\frac{1}{2}$
+ ·83

4·15 = $\frac{5}{8}$
+ ·83

4·98 = $\frac{3}{4}$
+ ·83

5·81 = $\frac{7}{8}$
+ ·83

6·64 = 1 inch broad.

The Tables advancing by $\frac{1}{4}$ of an inch in breadth are
cted in the same manner as the above.

TABLE III.*

SHOWING THE WEIGHT OF A LINEAL FOOT OF ROUND BAR IRON,

in Avoirdupois qrs. lbs. oz., from ⅛th of an Inch to 12 Inches Diameter, advancing by ⅛th of an Inch.

Inches.	qrs.	lbs.	oz.	Inches.	qrs.	lbs.	oz.	Inches.	qrs.	lbs.	oz.
⅛	0	0	0·4	4⅛	1	16	4·1	8⅛	6	3	10·1
¼	0	0	2·6	4¼	1	18	15·8	8¼	6	8	15·4
⅜	0	0	5·8	4⅜	1	21	12·6	8⅜	6	14	5·8
½	0	0	10·4	4½	1	24	10·8	8½	6	19	13·6
⅝	0	1	0·1	4⅝	1	27	10·2	8⅝	6	25	6·7
¾	0	1	7·3	4¾	2	2	11·0	8¾	7	3	1·0
⅞	0	1	15·8	4⅞	2	5	13·1	8⅞	7	8	12·7
1	0	2	9·4	5	2	9	0·6	9	7	14	9·6
1⅛	0	3	4·8	5⅛	2	12	5·2	9⅛	7	20	7·8
1¼	0	4	1·1	5¼	2	15	11·0	9¼	7	26	7·4
1⅜	0	4	14·7	5⅜	2	19	2·4	9⅜	8	4	8·2
1½	0	5	13·7	5½	2	22	11·0	9½	8	10	10·4
1⅝	0	6	13·9	5⅝	2	26	4·8	9⅝	8	16	13·8
1¾	0	7	15·5	5¾	3	2	0·1	9¾	8	23	2·6
1⅞	0	9	2·4	5⅞	3	5	12·6	9⅞	9	1	8·6
2	0	10	6·5	6	3	9	10·4	10	9	8	0·0
2⅛	0	11	12·0	6⅛	3	13	8·6	10⅛	9	14	8·6
2¼	0	13	1·7	6¼	3	17	9·0	10¼	9	21	2·6
2⅜	0	14	10·7	6⅜	3	21	10·6	10⅜	9	27	13·8
2½	0	16	4·1	6½	3	25	13·6	10½	10	6	10·4
2⅝	0	17	14·8	6⅝	4	2	1·8	10⅝	10	13	8·2
2¾	0	19	9·6	6¾	4	6	7·4	10¾	10	20	7·4
2⅞	0	21	8·0	6⅞	4	11	1·4	10⅞	10	27	7·8
3	0	23	6·5	7	4	15	6·4	11	11	6	9·6
3⅛	0	25	6·4	7⅛	4	19	15·5	11⅛	11	13	12·6
3¼	0	27	7·6	7¼	4	24	10·6	11¼	11	21	1·0
3⅜	1	1	10·0	7⅜	5	1	6·7	11⅜	12	0	0·6
3½	1	3	13·9	7½	5	6	4·0	11½	12	7	13·6
3⅝	1	6	2·8	7⅝	5	11	2·6	11⅝	12	15	5·8
3¾	1	8	9·2	7¾	5	16	2·7	11¾	12	22	15·4
3⅞	1	11	0·9	7⅞	5	21	3·7	11⅞	13	2	10·2
4	1	13	9·9	8	5	26	6·4	12	13	10	6·4

* James Foden.

TABLE IV.*

…WING THE WEIGHT OF A LINEAL FOOT OF SQUARE BAR IRON,

…irdupois qrs. lbs. oz., from ⅛th of an Inch to 12 Inches, advancing by ⅛th of an Inch.

Inches.	qrs.	lbs.	oz.	Inches.	qrs.	lbs.	oz.	Inches.	qrs.	lbs.	oz.
⅛	0	0	0·8	4⅛	2	0	7·8	8⅛	7	23	2·7
¼	0	0	3·3	4¼	2	3	14·1	8¼	8	1	15·4
⅜	0	0	7·4	4⅜	2	7	6·4	8⅜	8	8	13·8
½	0	0	13·2	4½	2	11	3·7	8½	8	15	13·9
⅝	0	1	5·1	4⅝	2	14	13·6	8⅝	8	22	15·6
¾	0	1	13·8	4¾	2	18	14·3	8¾	9	2	2·0
⅞	0	2	8·6	4⅞	2	22	15·1	8⅞	9	9	8·0
[illegible]	0	3	4·9	5	2	27	0·0	9	9	16	14·7
[illegible]	0	4	3·2	5⅛	3	3	3·2	9⅛	9	24	7·1
[illegible]	0	5	2·7	5¼	3	7	8·1	9¼	10	4	1·0
[illegible]	0	6	4·1	3⅜	3	11	14·2	9⅜	10	11	12·7
[illegible]	0	7	7·5	5½	3	16	6·8	9½	10	19	10·0
[illegible]	0	8	12·0	5⅝	3	21	0·9	9⅝	10	27	9·0
[illegible]	0	10	1·6	5¾	3	25	12·2	9¾	11	7	9·7
[illegible]	0	11	10·4	5⅞	4	2	8·1	9⅞	11	15	12·0
[illegible]	0	13	4·5	6	4	7	8·3	10	11	24	0·0
[illegible]	0	14	15·4	6⅛	4	12	8·8	10⅛	12	4	5·6
[illegible]	0	16	12·9	6¼	4	17	11·0	10¼	12	12	12·9
[illegible]	0	18	11·0	6⅜	4	22	14·8	10⅜	12	21	5·8
[illegible]	0	20	12·0	6½	5	0	4·3	10½	13	2	0·4
[illegible]	0	22	13·1	6⅝	5	5	11·4	10⅝	13	10	12·7
[illegible]	0	25	1·7	6¾	5	11	4·2	10¾	13	19	10·6
[illegible]	0	27	6·4	6⅞	5	16	14·7	10⅞	14	0	10·2
[illegible]	1	1	14·1	7	5	22	10·8	11	14	9	11·5
[illegible]	1	4	5·6	7⅛	6	0	8·6	11⅛	14	18	14·4
[illegible]	1	6	15·6	7¼	6	6	8·1	11¼	15	0	3·0
[illegible]	1	9	11·6	7⅜	6	12	9·2	11⅜	15	9	9·2
[illegible]	1	12	9·1	7½	6	18	12·0	11½	15	19	1·1
[illegible]	1	15	8·3	7⅝	6	25	0·4	11⅝	16	0	10·6
[illegible]	1	18	9·1	7¾	7	3	6·5	11¾	16	10	5·8
[illegible]	1	21	12·6	7⅞	7	9	14·2	11⅞	16	20	2·7
[illegible]	1	25	1·9	8	7	16	7·6	12	17	2	1·2

* James Foden.

OBSERVATIONS ON TABLES III. AND IV.

The Tables of the weight of round and square bars of malleable iron have been obtained by the following approximate rules:

Rule 1.—For round bars. Multiply the square of the diameter in inches by the length in feet, and that product by 2·6. The product will be the weight in pounds avoirdupois, nearly.

Rule 2.—For square bars. Multiply the area of the end of the bar in inches by the length in feet, and that by 3·32. The product will be the weight in pounds avoirdupois, nearly.

Example 1.—What is the weight of a round bar of malleable iron $4\frac{1}{2}$ feet long, and $2\frac{1}{4}$ inches in diameter?

$2{\cdot}25^2 \times 4{\cdot}5 = 22{\cdot}78125 \times 2{\cdot}6 = 59{\cdot}23125$ lbs. $=$ 59 lbs. 3·7 oz.

Example 2.—Required the weight of a square bar of malleable iron whose length is $7\frac{1}{4}$ feet, and $1\frac{1}{2}$ inch square.

$1{\cdot}5^2 \times 7{\cdot}25 = 16{\cdot}3125 \times 3{\cdot}32 = 54{\cdot}1575$ lbs. $=$ 54 lbs. 2·52 oz.

J. F.

TABLE V.*

CONTAINING THE CIRCUMFERENCES FOR ANGLED IRON HOOPS,

From 6 Inches to 6 Feet Diameter, advancing by an Eighth of an Inch.

ANGLE OUTSIDE.

Diam. In.	Circum. Ft.	Circum. In.	Diam. Ft.	Diam. In.	Circum. Ft.	Circum. In.	Diam. Ft.	Diam. In.	Circum. Ft.	Circum. In.	Diam. Ft.	Diam. In.	Circum. Ft.	Circum. In.
6	1	5½		10	2	5¼	1	2	3	5	1	6	4	4¾
⅛	1	5⅞		⅛	2	5⅝		⅛	3	5⅛		⅛	4	5⅛
¼	1	6¼		¼	2	6		¼	3	5¾		¼	4	5⅜
⅜	1	6⅝		⅜	2	6⅜		⅜	3	6⅛		⅜	4	5¾
½	1	7		½	2	6¾		½	3	6½		½	4	6⅛
⅝	1	7⅜		⅝	2	7⅛		⅝	3	6⅞		⅝	4	6½
¾	1	7¾		¾	2	7½		¾	3	7⅛		¾	4	6⅞
⅞	1	8⅛		⅞	2	7⅞		⅞	3	7½		⅞	4	7¼
7	1	8½		11	2	8¼	1	3	3	7⅞	1	7	4	7⅝
⅛	1	8⅞		⅛	2	8½		⅛	3	8¼		⅛	4	8
¼	1	9¼		¼	2	8⅞		¼	3	8⅝		¼	4	8⅜
⅜	1	9½		⅜	2	9¼		⅜	3	9		⅜	4	8¾
½	1	9⅞		½	2	9⅝		½	3	9⅜		½	4	9⅛
⅝	1	10¼		⅝	2	10		⅝	3	9¾		⅝	4	9½
¾	1	10⅝		¾	2	10⅜		¾	3	10⅛		¾	4	9⅞
⅞	1	11		⅞	2	10¾		⅞	3	10½		⅞	4	10¼
8	1	11⅜	1	0	2	11⅛	1	4	3	10⅞	1	8	4	10⅝
⅛	1	11¾		⅛	2	11½		⅛	3	11¼		⅛	4	11
¼	2	0⅛		¼	2	11⅞		¼	3	11⅝		¼	4	11⅜
⅜	2	0½		⅜	3	0¼		⅜	3	11⅞		⅜	4	11⅝
½	2	0⅞		½	3	0⅝		½	4	0¼		½	5	0
⅝	2	1¼		⅝	3	1		⅝	4	0⅝		⅝	5	0⅜
¾	2	1⅝		¾	3	1⅜		¾	4	1		¾	5	0¾
⅞	2	2		⅞	3	1¾		⅞	4	1⅜		⅞	5	1⅛
9	2	2⅜	1	1	3	2	1	5	4	1¾	1	9	5	1½
⅛	2	2⅝		⅛	3	2⅜		⅛	4	2⅛		⅛	5	1⅞
¼	2	3		¼	3	2¾		¼	4	2½		¼	5	2¼
⅜	2	3⅜		⅜	3	3⅛		⅜	4	2⅞		⅜	5	2⅝
½	2	3¾		½	3	3½		½	4	3¼		½	5	3
⅝	2	4⅛		⅝	3	3⅞		⅝	4	3⅝		⅝	5	3⅜
¾	2	4½		¾	3	4¼		¾	4	4		¾	5	3¾
⅞	2	4⅞		⅞	3	4⅝		⅞	4	4⅜		⅞	5	4

* James Foden.

Diam.		Circum.		Diam.		Circum.		Diam.		Circum.		Diam.		C
Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	F
1	10	5	4⅜	2	3	6	7⅛	2	8	7	9¾	3	1	
	⅛	5	4¾		⅛	6	7½		⅛	7	10⅛		⅛	
	¼	5	5⅛		¼	6	7⅞		¼	7	10½		¼	
	⅜	5	5½		⅜	6	8⅛		⅜	7	10⅞		⅜	
	½	5	5⅞		½	6	8½		½	7	11¼		½	
	⅝	5	6¼		⅝	6	8⅞		⅝	7	11⅝		⅝	
	¾	5	6⅝		¾	6	9¼		¾	8	0		¾	
	⅞	5	7		⅞	6	9⅝		⅞	8	0⅜		⅞	
1	11	5	7⅜	2	4	6	10	2	9	8	0⅝	3	2	
	⅛	5	7¾		⅛	6	10⅜		⅛	8	1		⅛	
	¼	5	8⅛		¼	6	10¾		¼	8	1⅜		¼	
	⅜	5	8½		⅜	6	11⅛		⅜	8	1¾		⅜	
	½	5	8⅞		½	6	11½		½	8	2⅛		½	
	⅝	5	9¼		⅝	6	11⅞		⅝	8	2½		⅝	
	¾	5	9⅝		¾	7	0¼		¾	8	2⅞		¾	
	⅞	5	9⅞		⅞	7	0⅝		⅞	8	3¼		⅞	
2	0	5	10¼	2	5	7	1	2	10	8	3⅝	3	3	
	⅛	5	10⅝		⅛	7	1⅜		⅛	8	4		⅛	
	¼	5	11		¼	7	1¾		¼	8	4⅜		¼	
	⅜	5	11⅜		⅜	7	2		⅜	8	4¾		⅜	
	½	5	11¾		½	7	2⅜		½	8	5⅛		½	
	⅝	6	0⅛		⅝	7	2¾		⅝	8	5½		⅝	
	¾	6	0½		¾	7	3⅛		¾	8	5¾		¾	
	⅞	6	0⅞		⅞	7	3½		⅞	8	6⅛		⅞	
2	1	6	1¼	2	6	7	3⅞	2	11	8	6½	3	4	
	⅛	6	1⅝		⅛	7	4¼		⅛	8	6⅞		⅛	
	¼	6	2		¼	7	4⅝		¼	8	7¼		¼	
	⅜	6	2⅜		⅜	7	5		⅜	8	7⅝		⅜	
	½	6	2¾		½	7	5⅜		½	8	8		½	
	⅝	6	3		⅝	7	5¾		⅝	8	8⅜		⅝	
	¾	6	3⅜		¾	7	6⅛		¾	8	8¾		¾	
	⅞	6	3¾		⅞	7	6½		⅞	8	9⅛		⅞	
2	2	6	4⅛	2	7	7	6⅞	3	0	8	9½	3	5	
	⅛	6	4½		⅛	7	7⅛		⅛	8	9⅞		⅛	
	¼	6	4⅞		¼	7	7½		¼	8	10¼		¼	
	⅜	6	5¼		⅜	7	7⅞		⅜	8	10⅝		⅜	
	½	6	5⅝		½	7	8¼		½	8	11		½	
	⅝	6	6		⅝	7	8⅝		⅝	8	11¼		⅝	
	¾	6	6⅜		¾	7	9		¾	8	11⅝		¾	
	⅞	6	6¾		⅞	7	9⅜		⅞	9	0		⅞	

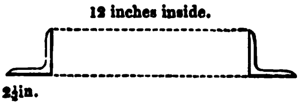
iam.	Circum.	Diam.	Circum.	Diam.	Circum.	Diam.	Circum.
In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.
6	10 3	3 11	11 5¾	4 4	12 8⅜	4 9	13 11
⅛	10 3⅜	⅛	11 6⅛	⅛	12 8¾	⅛	13 11⅜
¼	10 3¾	¼	11 6½	¼	12 9⅛	¼	13 11¾
⅜	10 4⅛	⅜	11 6⅞	⅜	12 9½	⅜	14 0⅛
½	10 4½	½	11 7⅛	½	12 9⅞	½	14 0½
⅝	10 4⅞	⅝	11 7½	⅝	12 10¼	⅝	14 0⅞
¾	10 5¼	¾	11 7⅞	¾	12 10½	¾	14 1¼
⅞	10 5⅝	⅞	11 8¼	⅞	12 10⅞	⅞	14 1⅝
7	10 6	4 0	11 8⅝	4 5	12 11¼	4 10	14 2
⅛	10 6⅜	⅛	11 9	⅛	12 11⅝	⅛	14 2⅜
¼	10 6¾	¼	11 9⅜	¼	13 0	¼	14 2¾
⅜	10 7⅛	⅜	11 9¾	⅜	13 0⅜	⅜	14 3
½	10 7½	½	11 10⅛	½	13 0¾	½	14 3⅜
⅝	10 7⅞	⅝	11 10½	⅝	13 1⅛	⅝	14 3¾
¾	10 8¼	¾	11 10⅞	¾	13 1½	¾	14 4⅛
⅞	10 8½	⅞	11 11¼	⅞	13 1⅞	⅞	14 4½
8	10 8⅞	4 1	11 11⅝	4 6	13 2¼	4 11	14 4⅞
⅛	10 9¼	⅛	12 0	⅛	13 2⅝	⅛	14 5¼
¼	10 9⅝	¼	12 0¼	¼	13 3	¼	14 5⅝
⅜	10 10	⅜	12 0⅝	⅜	13 3⅜	⅜	14 6
½	10 10⅜	½	12 1	½	13 3¾	½	14 6⅜
⅝	10 10¾	⅝	12 1⅜	⅝	13 4⅛	⅝	14 6¾
¾	10 11⅛	¾	12 1¾	¾	13 4⅜	¾	14 7⅛
⅞	10 11½	⅞	12 2⅛	⅞	13 4¾	⅞	14 7½
3 9	10 11⅞	4 2	12 2½	4 7	13 5⅛	5 0	14 7⅞
⅛	11 0¼	⅛	12 2⅞	⅛	13 5½	⅛	14 8⅛
¼	11 0⅝	¼	12 3¼	¼	13 5⅞	¼	14 8½
⅜	11 1	⅜	12 3⅝	⅜	13 6¼	⅜	14 8⅞
½	11 1⅜	½	12 4	½	13 6⅝	½	14 9¼
⅝	11 1¾	⅝	12 4⅜	⅝	13 7	⅝	14 9⅝
¾	11 2	¾	12 4¾	¾	13 7⅜	¾	14 10
⅞	11 2⅜	⅞	12 5⅛	⅞	13 7¾	⅞	14 10⅜
3 10	11 2¾	4 3	12 5½	4 8	13 8⅛	5 1	14 10¾
⅛	11 3⅛	⅛	12 5¾	⅛	13 8½	⅛	14 11⅛
¼	11 3½	¼	12 6⅛	¼	13 8⅞	¼	14 11½
⅜	11 3⅞	⅜	12 6½	⅜	13 9¼	⅜	14 11⅞
½	11 4¼	½	12 6⅞	½	13 9⅝	½	15 0¼
⅝	11 4⅝	⅝	12 7¼	⅝	13 9⅞	⅝	15 0⅝
¾	11 5	¾	12 7⅝	¾	13 10¼	¾	15 1
⅞	11 5⅜	⅞	12 8	⅞	13 10⅝	⅞	15 1[illegible]

Diam.		Circum.		Diam.		Circum.		Diam.		Circum.		Diam.		Cir
Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.
5	2	15	1⅝	5	5	15	10½	5	8	16	7¼	5	10	17
	⅛	15	2		⅛	15	10⅞		⅛	16	7⅝		⅛	17
	¼	15	2⅜		¼	15	11¼		¼	16	8		¼	17
	⅜	15	2¾		⅜	15	11⅝		⅜	16	8⅜		⅜	17
	½	15	3⅛		½	16	0		½	16	8¾		½	17
	⅝	15	3½		⅝	16	0¼		⅝	16	9⅛		⅝	17
	¾	15	3⅞		¾	16	0⅝		¾	16	9½		¾	17
	⅞	15	4¼		⅞	16	1		⅞	16	9⅞		⅞	17
5	3	15	4⅝	5	6	16	1⅜	5	9	16	10¼	5	11	17
	⅛	15	5		⅛	16	1¾		⅛	16	10⅝		⅛	17
	¼	15	5⅜		¼	16	2⅛		¼	16	10⅞		¼	17
	⅜	15	5¾		⅜	16	2½		⅜	16	11¼		⅜	17
	½	15	6⅛		½	16	2⅞		½	16	11⅝		½	17
	⅝	15	6½		⅝	16	3¼		⅝	17	0		⅝	17
	¾	15	6⅞		¾	16	3⅝		¾	17	0⅜		¾	17
	⅞	15	7⅛		⅞	16	4		⅞	17	0¾		⅞	17
5	4	15	7½	5	7	16	4⅜					6	0	17
	⅛	15	7⅞		⅛	16	4¾							
	¼	15	8¼		¼	16	5⅛							
	⅜	15	8⅝		⅜	16	5⅜							
	½	15	9		½	16	5¾							
	⅝	15	9⅜		⅝	16	6⅛							
	¾	15	9¾		¾	16	6½							
	⅞	15	10⅛		⅞	16	6⅞							

OBSERVATIONS ON TABLE V.

As this Table, together with the following one, will be useful to those smiths who chiefly work angled iron, it will be necessary to remark, that the observation made on Table I., respecting adding the thickness of the iron to the diameter, must also be attended to in this, with this difference, — the breadth of the angle must be added to the diameter.

Example.—Suppose, as in the following sectional figure, a hoop is wanted to be made of 2½-inch angled iron, whose diameter inside must be 12 inches. Here the 2½ inches must be added to the 12 inches, which raises the number to 1 foot 2½ inches. Looking into the Table, I find the circumference, or length of iron requisite for the hoop, is 3 feet 6½ inches.



J. F.

TABLE VI.*

CONTAINING THE CIRCUMFERENCES FOR ANGLED HOOPS,

From 6 Inches to 6 Feet Diameter, advancing by an Eighth of

ANGLE INSIDE.

Diam.	Circum.		Diam.		Circum.		Diam.		Circum.		Diam.	
In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.
6	1	8½		10	2	10¼	1	2	3	11⅞	1	6
⅛	1	8¾		⅛	2	10⅝		⅛	4	0⅜		⅛
¼	1	9⅜		¼	2	11		¼	4	0¾		¼
⅜	1	9¾		⅜	2	11½		⅜	4	1⅛		⅜
½	1	10¼		½	2	11⅞		½	4	1⅝		½
⅝	1	10⅝		⅝	3	0⅜		⅝	4	2		⅝
¾	1	11⅛		¾	3	0¾		¾	4	2½		¾
⅞	1	11½		⅞	3	1¼		⅞	4	2⅞		⅞
7	1	11⅞		11	3	1⅝	1	3	4	3⅜	1	7
⅛	2	0⅜		⅛	3	2		⅛	4	3¾		⅛
¼	2	0¾		¼	3	2½		¼	4	4⅛		¼
⅜	2	1¼		⅜	3	2⅞		⅜	4	4⅝		⅜
½	2	1⅝		½	3	3⅜		½	4	5		½
⅝	2	2		⅝	3	3¾		⅝	4	5½		⅝
¾	2	2½		¾	3	4¼		¾	4	5⅞		¾
⅞	2	2⅞		⅞	3	4⅝		⅞	4	6¼		⅞
8	2	3⅜	1	0	3	5	1	4	4	6¾	1	8
⅛	2	3¾		⅛	3	5½		⅛	4	7⅛		⅛
¼	2	4¼		¼	3	5⅞		¼	4	7⅝		¼
⅜	2	4⅝		⅜	3	6⅜		⅜	4	8		⅜
½	2	5		½	3	6¾		½	4	8½		½
⅝	2	5½		⅝	3	7⅛		⅝	4	8⅞		⅝
¾	2	5⅞		¾	3	7⅝		¾	4	9⅜		¾
⅞	2	6⅜		⅞	3	8		⅞	4	9¾		⅞
9	2	6¾	1	1	3	8½	1	5	4	10⅛	1	9
⅛	2	7¼		⅛	3	8⅞		⅛	4	10⅝		⅛
¼	2	7⅝		¼	3	9⅜		¼	4	11		¼
⅜	2	8		⅜	3	9¾		⅜	4	11½		⅜
½	2	8½		½	3	10⅛		½	4	11⅞		½
⅝	2	8⅞		⅝	3	10⅝		⅝	5	0¼		⅝
¾	2	9⅜		¾	3	11		¾	5	0¾		¾
⅞	2	9¾		⅞	3	11½		⅞	5	1⅛		⅞

* James Foden.

Diam.		Circum.		Diam.		Circum.		Diam.		Circum.		Diam.		Circum.	
	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.
	10	6	3¼	2	3	7	8⅜	2	8	9	1½	3	1	10	6⅝
	⅛	6	3¾		⅛	7	8⅞		⅛	9	2		⅛	10	7⅛
	¼	6	4⅛		¼	7	9¼		¼	9	2⅜		¼	10	7½
	⅜	6	4⅝		⅜	7	9¾		⅜	9	2⅞		⅜	10	8
	½	6	5		½	7	10⅛		½	9	3¼		½	10	8⅜
	⅝	6	5⅜		⅝	7	10½		⅝	9	3⅝		⅝	10	8¾
	¾	6	5⅞		¾	7	11		¾	9	4⅛		¾	10	9¼
	⅞	6	6¼		⅞	7	11⅜		⅞	9	4½		⅞	10	9⅝
	11	6	6¾	2	4	7	11¾	2	9	9	5	3	2	10	10⅛
	⅛	6	7⅛		⅛	8	0¼		⅛	9	5⅜		⅛	10	10½
	¼	6	7⅝		¼	8	0¾		¼	9	5⅞		¼	10	11
	⅜	6	8		⅜	8	1⅛		⅜	9	6¼		⅜	10	11⅜
	½	6	8⅜		½	8	1½		½	9	6⅝		½	10	11¾
	⅝	6	8⅞		⅝	8	2		⅝	9	7⅛		⅝	11	0¼
	¾	6	9¼		¾	8	2⅜		¾	9	7½		¾	11	0⅝
	⅞	6	9¾		⅞	8	2¾		⅞	9	8		⅞	11	1⅛
	0	6	10⅛	2	5	8	3¼	2	10	9	8⅜	3	3	11	1½
	⅛	6	10½		⅛	8	3⅝		⅛	9	8⅞		⅛	11	2
	¼	6	11		¼	8	4⅛		¼	9	9¼		¼	11	2⅜
	⅜	6	11⅜		⅜	8	4½		⅜	9	9⅝		⅜	11	2¾
	½	6	11⅞		½	8	5		½	9	10⅛		½	11	3¼
	⅝	7	0¼		⅝	8	5½		⅝	9	10½		⅝	11	3⅝
	¾	7	0¾		¾	8	5⅞		¾	9	11		¾	11	4⅛
	⅞	7	1⅛		⅞	8	6¼		⅞	9	11⅜		⅞	11	4½
	1	7	1⅝	2	6	8	6¾	2	11	9	11⅞	3	4	11	5
	⅛	7	2		⅛	8	7⅛		⅛	10	0¼		⅛	11	5⅜
	¼	7	2⅜		¼	8	7½		¼	10	0⅝		¼	11	5¾
	⅜	7	2⅞		⅜	8	8		⅜	10	1⅛		⅜	11	6¼
	½	7	3¼		½	8	8⅜		½	10	1½		½	11	6⅝
	⅝	7	3¾		⅝	8	8⅞		⅝	10	2		⅝	11	7⅛
	¾	7	4⅛		¾	8	9¼		¾	10	2⅜		¾	11	7½
	⅞	7	4½		⅞	8	9⅝		⅞	10	2¾		⅞	11	8
	2	7	5	2	7	8	10⅛	3	0	10	3¼	3	5	11	8⅜
	⅛	7	5⅜		⅛	8	10½		⅛	10	3⅝		⅛	11	8¾
	¼	7	5⅞		¼	8	11		¼	10	4⅛		¼	11	9¼
	⅜	7	6¼		⅜	8	11⅜		⅜	10	4½		⅜	11	9⅝
	½	7	6¾		½	8	11⅞		½	10	5		½	11	10⅛
	⅝	7	7⅛		⅝	9	0¼		⅝	10	5⅜		⅝	11	10½
	¾	7	7½		¾	9	0⅝		¾	10	5⅞		¾	11	10⅞
	⅞	7	8		⅞	9	1⅛		⅞	10	6¼		⅞	11	11⅜

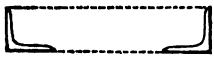
Diam.		Circum.		Diam.		Circum.		Diam.		Circum.		Diam.	
Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	[illegible]
3	6	11	11¾	3	11	13	4⅞	4	4	14	10	4	[illegible]
	⅛	12	0¼		⅛	13	5⅜		⅛	14	10½		
	¼	12	0⅝		¼	13	5¾		¼	14	10⅞		
	⅜	12	1⅛		⅜	13	6		⅜	14	11⅜		
	½	12	1½		½	13	6⅝		½	14	11¾		
	⅝	12	1⅞		⅝	13	7		⅝	15	0⅛		
	¾	12	2⅜		¾	13	7½		¾	15	0⅝		
	⅞	12	2¾		⅞	13	7⅞		⅞	15	1		
3	7	12	3¼	4	0	13	8⅜	4	5	15	1½	4	[illegible]
	⅛	12	3⅝		⅛	13	8¾		⅛	15	1⅞		
	¼	12	4⅛		¼	13	9¼		¼	15	2¼		
	⅜	12	4½		⅜	13	9⅝		⅜	15	2¾		
	½	12	4⅞		½	13	10		½	15	3⅛		
	⅝	12	5⅜		⅝	13	10½		⅝	15	3⅝		
	¾	12	5¾		¾	13	10⅞		¾	15	4		
	⅞	12	6¼		⅞	13	11⅜		⅞	15	4½		
3	8	12	6⅝	4	1	13	11¾	4	6	15	4⅞	4	[illegible]
	⅛	12	7		⅛	14	0¼		⅛	15	5¼		
	¼	12	7½		¼	14	0⅝		¼	15	5¾		
	⅜	12	7⅞		⅜	14	1		⅜	15	6⅛		
	½	12	8⅜		½	14	1½		½	15	6⅝		
	⅝	12	8¾		⅝	14	1⅞		⅝	15	7		
	¾	12	9¼		¾	14	2⅜		¾	15	7½		
	⅞	12	9⅝		⅞	14	2¾		⅞	15	7⅞		
3	9	12	10	4	2	14	3⅛	4	7	15	8¼	5	[illegible]
	⅛	12	10½		⅛	14	3½		⅛	15	8¾		
	¼	12	10⅞		¼	14	4		¼	15	9⅛		
	⅜	12	11⅜		⅜	14	4½		⅜	15	9⅝		
	½	12	11¾		½	14	4⅞		½	15	10		
	⅝	13	0¼		⅝	14	5⅜		⅝	15	10½		
	¾	13	0⅝		¾	14	5¾		¾	15	10⅞		
	⅞	13	1		⅞	14	6⅛		⅞	15	11¼		
3	10	13	1½	4	3	14	6⅝	4	8	15	11¾	5	[illegible]
	⅛	13	1⅞		⅛	14	7		⅛	16	0⅛		
	¼	13	2⅜		¼	14	7⅜		¼	16	0⅝		
	⅜	13	2¾		⅜	14	7⅞		⅜	16	1		
	½	13	3¼		½	14	8⅜		½	16	1½		
	⅝	13	3⅝		⅝	14	8¾		⅝	16	1⅞		
	¾	13	4		¾	14	9⅛		¾	16	2¼		
	⅞	13	4½		⅞	14	9⅝		⅞	16	2¾		

Diam.	Circum.	Diam.	Circum.	Diam.	Circum.	Diam.	Circum.
In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.	Ft. In.
2	17 8¼	5 5	18 6¼	5 8	19 4⅞	5 10	19 11⅝
⅛	17 8¾	⅛	18 7	⅛	19 5¼	⅛	20 0⅛
¼	17 9⅛	¼	18 7⅜	¼	19 5¾	¼	20 0½
⅜	17 9½	⅜	18 7⅞	⅜	19 6⅛	⅜	20 1
½	17 10	½	18 8¼	½	19 6½	½	20 1⅜
⅝	17 10⅜	⅝	18 8¾	⅝	19 7	⅝	20 1⅞
¾	17 10⅞	¾	18 9⅛	¾	19 7⅜	¾	20 2¼
⅞	17 11¼	⅞	18 9½	⅞	19 7⅞	⅞	20 2⅝
3	17 11¾	5 6	18 10	5 9	19 8¼	5 11	20 3⅛
⅛	18 0⅛	⅛	18 10⅜	⅛	19 8⅝	⅛	20 3½
¼	18 0½	¼	18 10⅞	¼	19 9⅛	¼	20 4
⅜	18 1	⅜	18 11¼	⅜	19 9½	⅜	20 4⅜
½	18 1⅜	½	18 11¾	½	19 10	½	20 4¾
⅝	18 1⅞	⅝	19 0⅛	⅝	19 10⅜	⅝	20 5¼
¾	18 2¼	¾	19 0½	¾	19 10⅞	¾	20 5⅝
⅞	18 2¾	⅞	19 1	⅞	19 11¼	⅞	20 6⅛
4	18 3⅛	5 7	19 1⅜			6 0	20 6½
⅛	18 3½	⅛	19 1⅞				
¼	18 4	¼	19 2¼				
⅜	18 4⅜	⅜	19 2¾				
½	18 4⅞	½	19 3⅛				
⅝	18 5¼	⅝	19 3½				
¾	18 5¾	¾	19 4				
⅞	18 6⅛	⅞	19 4⅜				

OBSERVATIONS ON TABLE VI.

The observations respecting this Table are the reverse to those on the preceding one,—viz. the breadth of the angle must be taken from the diameter,—for this reason, that the diameter is taken from outside to outside of the ring, as in the following sectional figure:—

12 inches outside.



2½ in.

Suppose a ring is to be made of angled iron, whose diameter outside is to be 12 inches, the breadth of the angle 2½ inches; then, by taking 2½ inches from 12 inches, we have left 9½ inches. Looking into the Table in the column of diameters, I find in the circumference column, opposite 9½ inches, 2 feet 8½ inches, which is the length of iron necessary for the ring.

It has been already observed, that between angled and plain iron a considerable difference exists with regard to the proportion of the circumference to the diameter: this is owing to the angle or flange on one side of the bar, and when the iron is formed into a hoop: it contracts more or less, as the angle or flange may be inside or outside of the hoop. From repeated experiments on this subject, I have ascertained that the proportions of the diameters to the circumferences are as follows:—For the angle inside

as 1 : 3·4248, and for the angle outside the hoop, as 1 : 2·9312 : : Diam : Circumf.

The method used in obtaining the numbers in these Tables of Circumferences of angled iron is, for the angle inside by adding $\frac{1}{8}$th of 3·4248, or ·4281 as a constant number; and for the angle outside, by constantly adding $\frac{1}{8}$th of 2·9312, or ·3664.

Example 1.—For a hoop with the angle or flange inside, beginning with 2 feet diameter.

3·4248 × 2 = 2·8496 feet, and ·8496 × 12 = 10·1952 inches, and this decimal ·1952 × $\frac{1}{8}$,

```
              in.
6 feet     10·1952 × 8 = 1/8
           + ·4281
           -------
              6233 × 8 = 1/8
           + ·4281
           -------
6· in.     11·0514 × 8 =
           + ·4281
           -------
              4795 × 8 = 3/8, &c.
```

Ex. 2.—For a hoop whose angle or flange is outside, commencing with a diameter of 3 feet.

2·9312 × 3 = 8·7936 ft., and ·7936 × 12 = 9·5232 in., and ·5232 × 8 = $\frac{1}{8}$,

```
Hence, 8 feet 9 in. ·5232 × 8 = 1/8
                     3664
                     ----
                     8896 × 8 = 7/8
                     3664
                     ----
            10 in.  ·2560 × 8 = 1/8
                     3664
                     ----
                     6224 × 8 = 5/8, &c.
```

Problem.—To find the circumference of an ellipse, or an oval hoop or ring.

Rule.—Add the length of the two axes together, and multiply the sum by 1·5708 for the circumference; or as it may be used in the Table of Circumferences, take half the sum of the axes as a diameter, with the breadth of the iron added, and enter the Table of Circumferences where it will be found.

Ex. Required the circumference of an elliptical hoop, whose axes are $18\frac{1}{4}$ and 13 inches, the thickness of the iron being $2\frac{1}{2}$ inches.

$$\begin{array}{r l} & 18\frac{1}{4} \\ & 13 \\ \hline \frac{1}{2})\!\! & 31\frac{1}{4} \\ \hline & 15\frac{5}{8} \\ + & 2\frac{1}{2} \text{ thickness.} \\ \hline & 18\frac{1}{8} \text{ inches the diameter.} \end{array}$$

Entering into the Table of Diameter with $18\frac{1}{4}$ inches, the circumference will be found to be 4 feet $9\frac{1}{4}$ inches.

In constructing elliptical hoops of angled iron, with the angle outside, reference must be made to the Tables for hoops of angled iron: the operation will be similar to the above example. But in hoops where the angle is inside, the thickness of the iron must be taken from half the sum of the axes.

Note.—It must be observed, that in the examples given in the Observations on Table I., and also on hoops formed of angled iron, that those circumferences are nothing more than the ends of the iron meeting together: therefore, every smith must allow for the thickening of the ends of the metal previous to scarving the same in order to weld it.

J. F.

Proportional breadths for hexagonal or six-sided Nuts for wrought-iron Bolts.

Dia. of bolts.	Breadth of nuts.	Dia. of bolts.	Breadth of nuts.
3/8	3/4 inch.	1 1/8	1 15/16 inch.
1/2	7/8 "	1 1/4	2 3/16 "
5/8	1 1/8 "	1 3/8	2 3/8 "
3/4	1 5/16 "	1 1/2	2 9/16 "
7/8	1 1/2 "	1 5/8	2 3/4 "
1	1 3/4 "	1 3/4	3 "

Note.—The thickness of the nut is equal the bolt's diameter.

WEIGHT OF A SUPERFICIAL FOOT OF PLATE OR SHEET IRON, COPPER, AND BRASS, IN POUNDS.

Thickness in parts of an inch.	Iron.	Thickness by the wire gauge. No.	Iron.	Copper.	Brass.	Thickness by the wire gauge. No.	Iron.	Copper.	Brass.
1/32	1·25	1	12·5	14·5	13·75	16	2·5	2·9	2·75
1/16	2·5	2	12	13·9	13·2	17	2·18	2·52	2·4
1/8	5	3	11	12·75	12·1	18	1·86	2·15	2·04
3/16	7·5	4	10	11·6	11	19	1·7	1·97	1·87
1/4	10	5	8·74	1·01	9·61	20	1·54	1·78	1·69
5/16	12·5	6	8·12	9·4	8·93	21	1·4	1·62	1·54
3/8	15	7	7·5	8·7	8·25	22	1·25	1·45	1·37
7/16	17·5	8	6·86	7·9	7·54	23	1·12	1·3	1·23
1/2	20	9	6·24	7·2	6·86	24	1	1·16	1·1
9/16	22·5	10	5·62	6·5	6·18	25	·9	1·04	·99
5/8	25	11	5	5·8	5·5	26	·8	·92	·88
11/16	27·5	12	4·38	5·08	4·81	27	·72	·83	·79
3/4	30	13	3·75	4·34	4·12	28	·64	·74	·7
7/8	35	14	3·12	3·6	3·43	29	·56	·64	·61
1	40	15	2·82	3·27	3·1	30	·5	·58	·55

Note.—No. 1 wire gauge equal $\frac{5}{16}$ths of an inch.

„ 4	„	$\frac{1}{4}$	„
„ 7	„	$\frac{3}{16}$	„
„ 11	„	$\frac{1}{8}$	„
„ 16	„	$\frac{1}{16}$	„
„ 22	„	$\frac{1}{32}$	„

The great variety of thicknesses into which copper is manufactured, causes in trade the weight to be named whereby to determine the thickness required, the unit being that of a common sheet, so designated, viz., 4 feet by 2 feet, in lbs.; thus,

A 70 lb. plate is $\frac{3}{16}$ths of an inch in thickness.

46½	„	$\frac{1}{8}$	„
23	„	$\frac{1}{16}$	„
11½	„	$\frac{1}{32}$	„
6	„	$\frac{1}{64}$ &c., &c.	

The thickness of lead is also in common determined or understood by the weight, the unit being that of a square or superficial foot; thus,

4-lb. lead is $\frac{1}{16}$th of an inch in thickness.

6	„	$\frac{1}{10}$	„
7½	„	$\frac{1}{8}$	„
11	„	$\frac{3}{16}$	„
15	„	$\frac{1}{4}$	„

COMPARATIVE WEIGHTS OF DIFFERENT BODIES.

Bar iron being 1.		Cast iron being 1.		Dry deal being 1.	
Cast iron	= ·95	Bar iron	= 1·07	Cast iron	= 11·0
Steel	= 1·02	Steel	= 1·08	Cast tin	= 11·2
Copper	= 1·16	Brass	= 1·16	Brass	= 12·7
Brass	= 1·09	Copper	= 1·21	Copper	= 13·3
Lead	= 1·48	Lead	= 1·56	Lead	= 17·1

1. Suppose I have an article of plate iron, the weight of which is 728 lbs., but want the same of copper, and of similar dimensions, what will be its weight?

$$728 \times 1·16 = 844·48 \text{ lbs.}$$

2. A model of dry pine weighing $32\frac{1}{2}$ lbs., and in which the iron for its construction forms no material portion of the weight, what may I anticipate its weight to be in cast iron?

$$32{\cdot}5 \times 11 = 357{\cdot}5 \text{ lbs.}$$

Note.—It frequently occurs in the formation or construction of models, that neither the quality nor condition of the timber can be properly estimated, and in such cases it may be a near enough approximation to reckon 10 lbs. of cast iron to each lb. of model.

WEIGHTS OF 9-FEET LENGTHS OF CAST-IRON PIPES, OF VARIOUS DIAMETERS.

Diameter of bore.	Thickness of metal.	Diameter of flange.	Thickness of flange.	Diameter of circle through holes.	Diameter and number of holes.		Weight in cwts.	qrs.	lbs.
in.	in.	in.	in.	in.	in.				
2	$\frac{3}{8}$	$6\frac{1}{2}$	$\frac{9}{16}$	$4\frac{3}{4}$	$\frac{5}{8}$	4	0	3	0
3	$\frac{3}{8}$	$7\frac{1}{2}$	$\frac{5}{8}$	6	$\frac{5}{8}$	4	1	0	3
4	$\frac{1}{2}$	$9\frac{1}{2}$	$\frac{3}{4}$	$7\frac{3}{4}$	$\frac{3}{4}$	4	1	3	5
5	$\frac{1}{2}$	$10\frac{1}{2}$	$\frac{7}{8}$	$8\frac{3}{4}$	$\frac{3}{4}$	4	2	1	12
6	$\frac{5}{8}$	12	$\frac{7}{8}$	10	$\frac{7}{8}$	4	3	2	1
7	$\frac{5}{8}$	14	1	$11\frac{3}{4}$	$\frac{7}{8}$	6	4	3	17
8	$\frac{3}{4}$	15	1	$12\frac{3}{4}$	1	6	5	2	9
9	$\frac{3}{4}$	$16\frac{1}{2}$	$1\frac{1}{16}$	$14\frac{1}{4}$	1	6	6	1	12
10	$\frac{3}{4}$	$17\frac{1}{2}$	$1\frac{1}{8}$	$15\frac{1}{2}$	1	6	7	0	0
11	$\frac{7}{8}$	19	$1\frac{3}{16}$	$16\frac{3}{4}$	1	6	8	3	24
12	$\frac{7}{8}$	20	$1\frac{1}{4}$	$17\frac{3}{4}$	$1\frac{1}{8}$	6	9	3	5
13	$\frac{7}{8}$	21	$1\frac{1}{4}$	$18\frac{3}{4}$	$1\frac{1}{8}$	6	10	2	0
14	$\frac{7}{8}$	22	$1\frac{1}{4}$	$19\frac{3}{4}$	$1\frac{1}{8}$	8	11	0	26
15	$\frac{7}{8}$	23	$1\frac{1}{4}$	$20\frac{3}{4}$	$1\frac{1}{8}$	8	12	0	25
16	$\frac{7}{8}$	$24\frac{1}{2}$	$1\frac{5}{16}$	22	$1\frac{1}{4}$	8	12	3	8
17	$\frac{7}{8}$	$25\frac{1}{2}$	$1\frac{5}{16}$	23	$1\frac{1}{4}$	8	13	2	17
18	1	$26\frac{1}{2}$	$1\frac{3}{8}$	24	$1\frac{1}{4}$	8	16	1	15
19	1	28	$1\frac{3}{8}$	25	$1\frac{3}{8}$	8	17	2	13
20	1	29	$1\frac{3}{8}$	26	$1\frac{3}{8}$	8	18	0	26

Weights of Leaden Pipes.

¾-inch bore	weighs		10 lbs.	per yard.
1	”	”	12	”
1¼	”	”	16	”
1½	”	”	18	”
1¾	”	”	21	”
2	”	”	24	”

TO ASCERTAIN THE WEIGHTS OF PIPES OF VARIOUS METALS, AND ANY DIAMETER REQUIRED.

Thickness in parts of an inch.	Wrought iron.	Copper.			Lead.		
1/32	·326	11½ lbs. plate		·38	2 lbs. lead		·483
1/16	·653	23½	”	·76	4	”	·967
3/32	·976	35	”	1·14	5½	”	1·45
1/8	1·3	46½	”	1·52	8	”	1·933
5/32	1·627	58	”	1·9	9¼	”	2·417
3/16	1·95	70	”	2·28	11	”	2·9
7/32	2·277	80½	”	2·66	13	”	3·383
1/4	2·6	93	”	3·04	15	”	3·867

Rule.—To the interior diameter of the pipe, in inches, add the thickness of the metal; multiply the sum by the decimal numbers opposite the required thickness and under the metal's name; also by the length of the pipe in feet, and the product is the weight of the pipe in lbs.

1. Required the weight of a copper pipe whose interior diameter is 7½ inches, its length 6¼ feet, and the metal ⅛ of an inch in thickness.

$$7{\cdot}5 + {\cdot}125 = 7{\cdot}625 \times 1{\cdot}52 \times 6{\cdot}25 = 72{\cdot}4 \text{ lbs.}$$

2. What is the weight of a leaden pipe 18½ feet in length, 3 inches interior diameter, and the metal ¼ of an inch in thickness?

$$3 + {\cdot}25 = 3{\cdot}25 \times 3{\cdot}867 \times 18{\cdot}5 = 232{\cdot}5 \text{ lbs.}$$

Note.—Weight of a cubic inch of

Lead	equal	·4103	lb.
Copper, sheet	„	·3225	„
Brass, do.	„	·3037	„
Iron, do.	„	·279	„
Iron, cast	„	·263	„
Tin, do.	„	·2636	„
Zinc, do,	„	·26	„
Water	„	·03617	„

WEIGHT OF CAST-IRON BALLS.

Diameter in inches.	Weight in lbs.	Diameter in inches.	Weight in lbs.	Diameter in inches.	Weight in lbs.
2	1·10	6	29·72	10	137·71
2¼	1·57	6¼	33·62	10¼	148·28
2½	2·15	6½	37·80	10½	159·40
2¾	2·86	6¾	42·35	10¾	171·05
3	3·72	7	47·21	11	183·29
3¼	4·71	7¼	52·47	11¼	196·10
3½	5·80	7½	58·06	11½	209·43
3¾	7·26	7¾	64·09	11¾	223·40
4	8·81	8	70·49	12	237·94
4¼	10·57	8¼	77·32	12¼	253·13
4½	12·55	8½	84·56	12½	268·97
4¾	14·76	8¾	92·24	12¾	285·37
5	17·12	9	100·39	13	302·41
5¼	19·93	9¼	108·98	13¼	320·80
5½	22·91	9½	118·06	13½	338·81
5¾	26·18	9¾	127·63	13¾	357·93

1. What will be the weight of a hollow ball or shell cast iron, the external diameter being 9½ and in-rnal diameter 8¾ inches?

Opposite 9½ are 118·06, and
Opposite 8¾ are 92·24, subtract

25·82 lbs., weight required.

2. Requiring to remove a cast-iron ball 37·8 lbs. in

weight, and in diameter 6½ inches, and repla one of lead of an equal weight, what must be meter of the leaden ball?

Weight of lead to that of cast iron = 1·56 (see Table, p

Then $\frac{6\cdot5^3}{1\cdot56} = \sqrt[3]{176} = 5\cdot6$ inches, the diameter.

TABLES BY WHICH TO FACILITATE THE ME TION OF TIMBER.

1. *Flat or Board Measure.*

Breadth in inches.	Area of a lineal foot.	Breadth in inches.	Area of a lineal foot.	Breadth in inches.	li
¼	·0208	4	·3334	8	
½	·0417	4¼	·3542	8¼	
¾	·0625	4½	·375	8½	
1	·0834	4¾	·3958	8¾	
1¼	·1042	5	·4167	9	
1½	·125	5¼	·4375	9¼	
1¾	·1459	5½	·4583	9½	
2	·1667	5¾	·4792	9¾	
2¼	·1875	6	·5	10	
2½	·2084	6¼	·5208	10¼	
2¾	·2292	6½	·5416	10½	
3	·25	6¾	·5625	10¾	
3¼	·2708	7	·5833	11	
3½	·2916	7¼	·6042	11¼	
3¾	·3125	7½	·625	11½	
		7¾	·6458	11¾	

Application and Use of the Table.

1. Required the number of square feet in or plank 16½ feet in length and 9¾ inches in b

Opposite 9¾ is ·8125 × 16·5 = 13·4 square feet

2. A board 1 foot 2¾ inches in breadth and in length; what is its superficial content in squa

Opposite 2¾ is ·2292, to which add the 1 foot; t
1·2292 × 21 = 25·8 square feet.

3. In a board 15½ inches at one end, 9 inches at the other, and 14½ feet in length, how many square feet?

$\frac{15 \cdot 5 + 9}{2} = 12\frac{1}{4}$, or 1·0208; and $1 \cdot 0208 \times 14 \cdot 5 = 14 \cdot 8$ sq. ft.

2. *Cubic or Solid Measure.*

Mean ¼ girt in inches.	Cubic feet in each lineal foot.	Mean ¼ girt in inches.	Cubic feet in each lineal foot.	Mean ¼ girt in inches.	Cubic feet in each lineal foot.
6	·25	14	1·361	22	3·362
6¼	·272	14¼	1·41	22¼	3·438
6½	·294	14½	1·46	22½	3·516
6¾	·317	14¾	1·511	22¾	3·598
7	·340	15	1·562	23	3·673
7¼	·364	15¼	1·615	23¼	3·754
7½	·39	15½	1·668	23½	3·835
7¾	·417	15¾	1·722	23¾	3·917
8	·444	16	1·777	24	4
8¼	·472	16¼	1·833	24¼	4·084
8½	·501	16½	1·89	24½	4·168
8¾	·531	16¾	1·948	24¾	4·254
9	·562	17	2·006	25	4·34
9¼	·594	17¼	2·066	25¼	4·428
9½	·626	17½	2·126	25½	4·516
9¾	·659	17¾	2·187	25¾	4·605
10	·694	18	2·25	26	4·694
10¼	·73	18¼	2·313	26¼	4·785
10½	·766	18½	2·376	26½	4·876
10¾	·803	18¾	2·442	26¾	4·969
11	·84	19	2·506	27	5·062
11¼	·878	19¼	2·574	27¼	5·158
11½	·918	19½	2·64	27½	5·252
11¾	·959	19¾	2·709	27¾	5·348
12	1·	20	2·777	28	5·444
12¼	1·042	20¼	2·898	28¼	5·542
12½	1·085	20½	2·917	28½	5·64
12¾	1·129	20¾	2·99	28¾	5·74
13	1·174	21	3·062	29	5·84
13¼	1·219	21¼	3·136	29¼	5·941
13½	1·265	21½	3·209	29½	6·044
13¾	1·313	21¾	3·285	29¾	6·146

In the cubic estimation of timber, custom has established the rule of ¼ the mean girt being the side of the square considered as the cross sectional dimensions; hence, multiply the number of cubic feet per lineal foot as in the Table of Cubic Measure opposite the ¼ girt, and the product is the solidity of the given dimensions in cubic feet.

Suppose the mean ¼ girt of a tree 21¼ inches, and its length 16 feet, what are its contents in cubic feet?

$$3{\cdot}136 \times 16 = 50{\cdot}176 \text{ cubic feet.}$$

Battens, Deals, and Planks, as imported into this country, are each similar in their various lengths, but differing in their widths and thicknesses, and hence their principal distinction: thus, a batten is 7 inche by 2½,—a deal 9 by 3,—and a plank 11 by 3,—thes being what are termed the standard dimensions, b which they are bought and sold, the length of ea being taken at 12 feet; therefore, in estimating f the proper value of any quantity, nothing more is quired than their lineal dimensions, by which to as tain the number of times 12 feet there are in the g whole.

Suppose I wish to purchase the following:

7 of	6 feet	$6 \times 7 =$	42 feet
5 „	14 „	$14 \times 5 =$	70 „
11 „	19 „	$19 \times 11 =$	209 „
and 6 „	21 „	$21 \times 6 =$	126 „

12)447(37·25 standard

TABLE SHOWING THE NUMBER OF LINEAL FEET OF SCANTLING OF VARIOUS DIMENSIONS WHICH ARE EQUAL TO A CUBIC FOOT.

	In.		Ft.	In.
2 inches by	2	require in length	36	0
	2½		28	9
	3		24	0
	3½		20	7
	4		18	0
	4½		16	0
	5		14	5
	5½		13	1
	6		12	0
	6½		11	1
	7		10	3
	7½		9	7
	8		9	0
	8½		8	6
	9		8	0
	9½		7	7
	10		7	3
	10½		6	10
	11		6	6
	11½		6	4
	12		6	0
3 inches by	3		16	0
	3½		13	8
	4		12	0
	4½		10	8
	5		9	7
	5½		9	0
	6		8	0
	6½		7	4
	7		6	10
	7½		6	4
	8		6	0
	8½		5	8
	9		5	4
	9½		5	0
	10		4	10
	10½		4	6
	11		4	4
	11½		4	2
	12		4	0

	In.		Ft.	In.
4 inches by	4	require in length	9	0
	4½		8	0
	5		7	2
	5½		6	6
	6		6	0
	6½		5	6
	7		5	1
	7½		4	9
	8		4	6
	8½		4	3
	9		4	0
	9½		3	9
	10		3	7
	10½		3	5
	11		3	3
	11½		3	2
	12		3	0
5 inches by	5		5	9
	5½		5	3
	6		4	10
	6½		4	5
	7		4	1
	7½		3	10
	8		3	7
	8½		3	5
	9		3	2
	9½		3	0
	10		2	10
	10½		2	9
	11		2	8
	11½		2	6
	12		2	4
6 inches by	6		4	0
	6½		3	8
	7		3	5
	7½		3	2
	8		3	0
	8½		2	10
	9		2	8

	In.		Ft.	In.
6 inches by	9½	require in length	2	6
	10		2	5
	10½		2	3
	11		2	2
	11½		2	1
	12		2	0
7 inches by	7		2	11
	7½		2	9
	8		2	6
	8½		2	5
	9		2	3
	9½		2	2
	10		2	1
	10½		1	11
	11		1	10
	11½		1	9
	12		1	8
8 inches by	8		2	3
	8½		2	1
	9		2	0
	9½		1	10
	10		1	9
	10½		1	8
	11		1	7
	11½		1	7
	12		1	6
9 inches by	9		1	9
	9½		1	8
	10		1	7
	10½		1	6
	11		1	5
	11½		1	4
	12		1	4
10 in. by	10		1	5
	10½		1	4
	11		1	4
	11½		1	3

INSTRUMENTAL ARITHMETIC,

OR UTILITY OF THE SLIDE RULE.

THE slide rule is an instrument by which the greater portion of operations in arithmetic and mensuration may be advantageously performed, provided the lines of division and gauge-points be made properly correct, and their several values familiarly understood.

The lines of division are distinguished by the letters A B C D; A B and C being each divided alike, and containing what is termed a double radius, or double series of logarithmic numbers, each series being supposed to be divided into 1000 equal parts, and distributed along the radius in the following manner:

From 1 to	2	contains	301	of those parts, being the log. of	2.
,,	3	,,	477	,,	3.
,,	4	,,	602	,,	4.
,,	5	,,	699	,,	5.
,,	6	,,	778	,,	6.
,,	7	,,	845	,,	7.
,,	8	,,	903	,,	8.
,,	9	,,	954	,,	9.
			1000 being the whole number.		

The line D on the improved rules consists of only a single radius; and although of larger radius, the logarithmic series is the same, and disposed of along the line in a similar proportion, forming exactly a line of *square* roots to the numbers on the lines B C.

NUMERATION.

ıeration teaches us to estimate or properly value nbers and divisions on the rule in an arithme- rm.

r values are all entirely governed by the value n the first figure, and being decimally reckoned, ɜ tenfold from the commencement to the ter- ›n of each radius: thus, suppose 1 at the joint the 1 in the middle of the rule is ten, and 1 ›nd, one hundred: again, suppose 1 at the joint n the middle is 100, and 1 or 10 at the end is &c., the intermediate divisions on which com- ıe whole system of its notation.

ɔ MULTIPLY NUMBERS BY THE RULE.

l on B opposite to the multiplier on A; and the number to be multiplied on B is the pro- ı A.

tiply 6 by 4.

on B to 4 on A; and against 6 on B is 24 on A. The ıs set, against 7 on B is 28 on A.

8	„	32	„
9	„	36	„
10	„	40	„
12	„	48	„
15	„	60	„
25	„	100, &c., &c.	

ɒ DIVIDE NUMBERS UPON THE RULE.

the divisor on B to 1 on A; and against the r to be divided on B is the quotient on A.

de 63 by 3.

on B to 1 on A; and against 63 on B is 21 on A.

PROPORTION, OR RULE OF THREE DIRECT.

Rule.—Set the first term on B to the second on A; and against the third upon B is the fourth upon A.

1. If 4 yards of cloth cost 38 shillings, what will 30 yards cost at the same rate?

Set 4 on B to 38 on A; and against 30 on B is 285 shillings on A.

2. Suppose I pay 31*s*. 6*d*. for 3 cwt. of iron, at what rate is that per ton? 1 *ton* = 20 *cwt*.

Set 3 upon B to 31·5 upon A; and against 20 upon B is 210 upon A.

RULE OF THREE INVERSE.

Rule.—Invert the slide, and the operation is the same as direct proportion.

1. I know that six men are capable of performing a certain given portion of work in eight days, but I want the same performed in three; how many men must there be employed?

Set 6 upon C to 8 upon A; and against 3 upon C is 16 upon A.

2. The lever of a safety-valve is 20 inches in length, and 5 inches between the fixed end and centre of the valve; what weight must there be placed on the end of the lever to equipoise a force or pressure of 40 lbs. tending to raise the valve?

Set 5 upon C to 40 upon A; and against 20 on C is 10 on A.

3. If $8\frac{3}{4}$ yards of cloth, $1\frac{1}{2}$ yard in width, be a sufficient quantity, how much will be required of that which is only $\frac{7}{8}$ths in width, to effect the same purpose?

Set 1·5 on C to 8·75 on A; and against ·875 upon C is 15 yards upon A.

SQUARE AND CUBE ROOTS OF NUMBERS.

On the engineer's rule, when the lines C and D are equal at both ends, C is a table of squares, and D a table of roots, as

Squares	1	4	9	16	25	36	49	64	81 on C.
Roots	1	2	3	4	5	6	7	8	9 on D.

To find the geometrical mean proportion between two numbers.

Set one of the numbers upon C to the same number upon D; and against the other number upon C is the mean number or side of an equal square upon D.

Required the mean proportion between 20 and 45.

Set 20 upon C to 20 upon D; and against 45 upon C is 30 on D.

To cube any number, set the number upon C to 1 or 10 upon D; and against the same number upon D is the cube number upon C.

Required the cube of 4.

Set 4 upon C to 1 or 10 upon D; and against 4 upon D is 64 upon C.

To extract the cube root of any number, invert the slide, and set the number upon B to 1 or 10 upon D; and where two numbers of equal value coincide on the lines B D, is the root of the given number.

Required the cube root of 64.

Set 64 upon B to 1 or 10 upon D; and against 4 upon B is 4 upon D, or root of the given number.

On the common rule, when 1 in the middle of the line C is set opposite to 10 on D, then C is a table of squares, and D a table of roots.

To cube any number by this rule, set the number upon C to 10 upon D; and against the same number upon D is the cube upon C.

MENSURATION OF SURFACE.

1. *Squares, Rectangles, &c.*

Rule.—When the length is given in feet and the breadth in inches, set the breadth on B to 12 on A; and against the length on A is the content in square feet on B.

If the dimensions are all inches, set the breadth on B to 144 upon A; and against the length upon A is the number of square feet on B.

Required the content of a board 15 inches broad and 14 feet long.

Set 15 upon B to 12 upon A; and against 14 upon A is 17·5 square feet on B.

2. *Circles, Polygons, &c.*

Rule.—Set ·7854 upon C to 1 or 10 upon D; then will the lines C and D be a table of areas and diameters.

Areas	3·14	7·06	12·56	19·63	28·27	38·48	50·26	63·61	upon C.
Diam.	2	3	4	5	6	7	8	9	upon D.

In the common rule, set ·7854 on C to 10 on D; then C is a line or table of areas, and D of diameters, as before.

Set 7 upon B to 22 upon A; then B and A form or become a table of diameters and circumferences of circles.

Cir.	3·14	6·28	9·42	12·56	15·7	18·85	22	25·13	28·27	upon A.
Dia.	1	2	3	4	5	6	7	8	9	upon B.

Polygons from 3 *to* 12 *sides.*—Set the gauge-point upon C to 1 or 10 upon D; and against the length of one side upon D is the area upon C.

Sides	3	5	6	7	8	9	10	11	12
Gauge-points	·433	1·7	2·6	3·63	4·82	6·18	7·69	9·37	11·17

Required the area of an equilateral triangle, each side 12 inches in length.

Set ·433 upon C to 1 upon D; and against 12 upon D are 62·5 square inches upon C.

TABLE OF GAUGE-POINTS FOR THE ENGINEER'S RULE.

Names.	F, F, F.	F, I, I.	I, I, I.	F, I.	I, I.	F.	I.
Cubic inches	578	83	1728	106	1273	105	121
Cubic feet	1	144	1	1833	22	121	33
Imp. gallons	163	231	277	294	353	306	529
Water in lbs.	16	23	276	293	352	305	528
Gold „	814	1175	141	149	178	155	269
Silver „	15	216	261	276	334	286	5
Mercury „	118	169	203	216	258	225	389
Brass „	193	177	333	354	424	369	637
Copper „	18	26	319	331	397	345	596
Lead „	141	203	243	258	31	27	465
Wro^t.iron „	207	297	357	338	453	394	682
Cast iron „	222	32	384	407	489	424	733
Tin „	219	315	378	401	481	419	728
Steel „	202	292	352	372	448	385	671
Coal „	127	183	22	33	28	242	42
Marble „	591	85	102	116	13	113	195
Freestone „	632	915	11	1162	14	141	21

FOR THE COMMON SLIDE RULE.

Names.	F, F, F.	F, I, I.	I, I, I.	F, I.	I, I.	F.	I.
Cubic inches	36	518	624	660	799	625	113
Cubic feet	625	9	108	114	138	119	206
Water in lbs.	10	144	174	184	22	191	329
Gold „	507	735	88	96	118	939	180
Silver „	938	136	157	173	208	173	354
Mercury „	738	122	127	132	162	141	242
Brass „	12	174	207	221	265	23	397
Copper „	112	163	196	207	247	214	371
Lead „	880	126	152	162	194	169	289
Wro^t.iron „	129	186	222	235	283	247	423
Cast iron „	139	2	241	254	304	265	458
Tin „	137	135	235	25	300	261	454
Steel „	136	183	22	233	278	239	418
Coal „	795	114	138	146	176	151	262
Marble „	370	53	637	725	81	72	121
Freestone „	394	57	69	728	873	755	132

MENSURATION OF SOLIDITY AND CA

General rule.—Set the length upon B to point upon A; and against the side of the diameter on D, are the cubic contents, o lbs. on C.

1. Required the cubic contents of a tre length, and 10 inches quarter girt.

Set 30 upon B to 144 (the gauge-point) upon A 10 upon D is 20·75 feet upon C.

2. In a cylinder 9 inches in length, a diameter, how many cubic inches?

Set 9 upon B to 1273 (the gauge-point) upon A 7 on D is 346 inches on C.

3. What is the weight of a bar of cast i square, and 6 feet long?

Set 6 upon B to 32 (the gauge-point) upon A; upon D is 168 lbs. upon C.

By the common rule.

4. Required the weight of a cylinder iron 10 inches long, and $5\frac{1}{2}$ diameter.

Set 10 upon B to 283 (G. Pt.) upon A; and ag D is 66·65 lbs. on C.

5. What is the weight of a dry rope 25 and 4 inches circumference?

Set 25 upon B to 47 (G. Pt.) upon A; and aga 53·16 lbs. on C.

6. What is the weight of a short-link yards in length, and $\frac{6}{16}$ths of an inch in

Set 30 upon B to 52 (G. Pt.) upon A; and aga 129·5 lbs. on C.

LAND SURVEYING.

If the dimensions taken are in chains, the gauge-int is 1 or 10; if in perches, 160; and if in yards, 40.—*Rule.* Set the length upon B to the gauge-int on A; and against the breadth upon A is the ntent in acres upon B.

1. Required the number of acres or contents of ield 20 chains 50 links in length, and 4 chains 40 ks in breadth.

Set 20·5 on B to 1 on A; and against 4·4 on A is 9 acres on B.

2. In a piece of ground 440 yards long, and 44 oad, how many acres?

Set 440 upon B to 4840 on A; and against 44 on A is cres on B.

POWER OF STEAM ENGINES.

Condensing Engines.—*Rule.* Set 3·5 on C to 10 on ; then D is a line of diameters for cylinders, and C e corresponding number of horses' power; thus,

Pr.	3½	4	5	6	8	10	12	16	20	25	30	40	50	on C.
D.	10 in.	10¾	12	13¼	15½	17	18¾	21½	24	26¾	29½	33¾	37¾	on D.

The same is effected on the common rule by setting on C to 12 on D.

Non-condensing Engines.—*Rule.* Set the pressure steam in lbs. per square inch on B to 4 upon A; d against the cylinder's diameter on D is the num-r of horses' power upon C.

Required the power of an engine, when the cylin-r is 20 inches diameter and steam 30 lbs. per uare inch.

Set 30 on B to 4 on A; and against 20 on D is 30 horses' wer on C.

The same is effected on the common rule b the force of the steam on B to 250 on A.

OF ENGINE BOILERS.

How many superficial feet are contained i 23 feet in length and $5\frac{1}{2}$ in width?

Set 1 upon B to 23 upon A; and against 5·5 126·5 square feet upon A.

If 5 square feet of boiler surface be suffi each horse-power, how many horses' power (is the boiler equal to?

Set 5 upon B to 126·5 upon A; and against 1 25·5 upon A.

COMMERCIAL TABLES.

TABLE BY WHICH TO FACILITATE THE CALCULATION OF BRITISH MONEY

No.	L.	S.	D.	L.	S.	D.	L.	S.	D.	L.	S.	D.	L.	S.	D.	L.	S.	D.	L.	S.	D.
	at ¼d.			at ½d.			at ¾d.			at 1d.			at 1¼d.			at 1½d.			at 1¾d.		
2	0	0	0½	0	0	1	0	0	1½	0	0	2	0	0	2½	0	0	3	0	0	3½
3	0	0	0¾	0	0	1½	0	0	2¼	0	0	3	0	0	3¾	0	0	4½	0	0	5¼
4	0	0	1	0	0	2	0	0	3	0	0	4	0	0	5	0	0	6	0	0	7
5	0	0	1¼	0	0	2½	0	0	3¾	0	0	5	0	0	6¼	0	0	7½	0	0	8¾
6	0	0	1½	0	0	3	0	0	4½	0	0	6	0	0	7½	0	0	9	0	0	10½
7	0	0	1¾	0	0	3½	0	0	5¼	0	0	7	0	0	8¾	0	0	10½	0	1	0¼
8	0	0	2	0	0	4	0	0	6	0	0	8	0	0	10	0	1	0	0	1	2
9	0	0	2¼	0	0	4½	0	0	6¾	0	0	9	0	0	11¼	0	1	1½	0	1	3¾
10	0	0	2½	0	0	5	0	0	7½	0	0	10	0	1	0½	0	1	3	0	1	5½
11	0	0	2¾	0	0	5½	0	0	8¼	0	0	11	0	1	1¾	0	1	4½	0	1	7¼
12	0	0	3	0	0	6	0	0	9	0	1	0	0	1	3	0	1	6	0	1	9
13	0	0	3¼	0	0	6½	0	0	9¾	0	1	1	0	1	4¼	0	1	7½	0	1	10¾
14	0	0	3½	0	0	7	0	0	10½	0	1	2	0	1	5½	0	1	9	0	2	0½
15	0	0	3¾	0	0	7½	0	0	11¼	0	1	3	0	1	6¾	0	1	10½	0	2	2¼
16	0	0	4	0	0	8	0	1	0	0	1	4	0	1	8	0	2	0	0	2	4
17	0	0	4¼	0	0	8½	0	1	0¾	0	1	5	0	1	9¼	0	2	1½	0	2	5¾
18	0	0	4½	0	0	9	0	1	1½	0	1	6	0	1	10½	0	2	3	0	2	7½
19	0	0	4¾	0	0	9½	0	1	2¼	0	1	7	0	1	11¾	0	2	4½	0	2	9¼
20	0	0	5	0	0	10	0	1	3	0	1	8	0	2	1	0	2	6	0	2	11
30	0	0	7½	0	1	3	0	1	10½	0	2	6	0	3	1½	0	3	9	0	4	4½
40	0	0	10	0	1	8	0	2	6	0	3	4	0	4	2	0	5	0	0	5	10
50	0	1	0½	0	2	1	0	3	1½	0	4	2	0	5	2½	0	6	3	0	7	3½
60	0	1	3	0	2	6	0	3	9	0	5	0	0	6	3	0	7	6	0	8	9
70	0	1	5½	0	2	11	0	4	4½	0	5	10	0	7	3½	0	8	9	0	10	2½
80	0	1	8	0	3	4	0	5	0	0	6	8	0	8	4	0	10	0	0	11	8
90	0	1	10½	0	3	9	0	5	7½	0	7	6	0	9	4½	0	11	3	0	13	1½
100	0	2	1	0	4	2	0	6	3	0	8	4	0	10	5	0	12	6	0	14	7
200	0	4	2	0	8	4	0	12	6	0	16	8	1	0	10	1	5	0	1	9	2
300	0	6	3	0	12	6	0	18	9	1	5	0	1	11	3	1	17	6	2	3	9
400	0	8	4	0	16	8	1	5	0	1	13	4	2	1	8	2	10	0	2	18	4
500	0	10	5	1	0	10	1	11	3	2	1	8	2	12	1	3	2	6	3	12	11
600	0	12	6	1	5	0	1	17	6	2	10	0	3	2	6	3	15	0	4	7	6
700	0	14	7	1	9	2	2	3	9	2	18	4	3	12	11	4	7	6	5	2	1
800	0	16	8	1	13	4	2	10	0	3	6	8	4	3	4	5	0	0	5	16	8
900	0	18	9	1	17	6	2	16	3	3	15	0	4	13	9	5	12	6	6	11	3
1000	1	0	10	2	1	8	3	2	6	4	3	4	5	4	2	6	5	0	7	5	10
2000	2	1	8	4	3	4	6	5	0	8	6	8	10	8	4	12	10	0	14	11	8
3000	3	2	6	6	5	0	9	7	6	12	10	0	15	12	6	18	15	0	21	17	6
4000	4	3	4	8	6	8	12	10	0	16	13	4	20	16	8	25	0	0	29	3	4
5000	5	4	2	10	8	4	15	12	6	20	16	8	26	0	10	31	5	0	36	9	2
6000	6	5	0	12	10	0	18	15	0	25	0	0	31	5	0	37	10	0	43	15	0
7000	7	5	10	14	11	8	21	17	6	29	3	4	36	9	2	43	15	0	51	0	10
8000	8	6	8	16	13	4	25	0	0	33	6	8	41	13	4	50	0	0	58	6	8
9000	9	7	6	18	15	0	28	2	6	37	10	0	46	17	6	56	5	0	65	12	6

MONEY TABLE—CONTINUED.

No.	L.	S.	D.	L.	S.	D.	L.	S.	D.	L.	S.	D.	L.	S.	D.	L.	S.	D.	L.
	at 2*d*.			at 2¼*d*.			at 2½*d*.			at 2¾*d*.			at 3*d*.			at 3¼*d*.			
2	0	0	4	0	0	4½	0	0	5	0	0	5½	0	0	6	0	0	6½	
3	0	0	6	0	0	6¾	0	0	7½	0	0	8¼	0	0	9	0	0	9¾	
4	0	0	8	0	0	9	0	0	10	0	0	11	0	1	0	0	1	1	
5	0	0	10	0	0	11¼	0	1	0½	0	1	1¾	0	1	3	0	1	4¼	
6	0	1	0	0	1	1½	0	1	3	0	1	4½	0	1	6	0	1	7½	
7	0	1	2	0	1	3¾	0	1	5½	0	1	7¼	0	1	9	0	1	10¾	
8	0	1	4	0	1	6	0	1	8	0	1	10	0	2	0	0	2	2	
9	0	1	6	0	1	8¼	0	1	10½	0	2	0¾	0	2	3	0	2	5¼	
10	0	1	8	0	1	10½	0	2	1	0	2	3½	0	2	6	0	2	8½	
11	0	1	10	0	2	0¾	0	2	3½	0	2	6¼	0	2	9	0	2	11¾	
12	0	2	0	0	2	3	0	2	6	0	2	9	0	3	0	0	3	3	
13	0	2	2	0	2	5¼	0	2	8½	0	2	11¾	0	3	3	0	3	6¼	
14	0	2	4	0	2	7½	0	2	11	0	3	2½	0	3	6	0	3	9½	
15	0	2	6	0	2	9¾	0	3	1½	0	3	5¼	0	3	9	0	4	0¾	
16	0	2	8	0	3	0	0	3	4	0	3	8	0	4	0	0	4	4	
17	0	2	10	0	3	2¼	0	3	6½	0	3	10¾	0	4	3	0	4	7¼	
18	0	3	0	0	3	4½	0	3	9	0	4	1½	0	4	6	0	4	10½	
19	0	3	2	0	3	6¾	0	3	11½	0	4	4¼	0	4	9	0	5	1¾	
20	0	3	4	0	3	9	0	4	2	0	4	7	0	5	0	0	5	5	
30	0	5	0	0	5	7½	0	6	3	0	6	10½	0	7	6	0	8	1½	
40	0	6	8	0	7	6	0	8	4	0	9	2	0	10	0	0	10	10	
50	0	8	4	0	9	4½	0	10	5	0	11	5½	0	12	6	0	13	6½	
60	0	10	0	0	11	3	0	12	6	0	13	9	0	15	0	0	16	3	
70	0	11	8	0	13	1½	0	14	7	0	16	0½	0	17	6	0	18	11½	
80	0	13	4	0	15	0	0	16	8	0	18	4	1	0	0	1	1	8	
90	0	15	0	0	16	10½	0	18	9	1	0	7½	1	2	6	1	4	4½	
100	0	16	8	0	18	9	1	0	10	1	2	11	1	5	0	1	7	1	
200	1	13	4	1	17	6	2	1	8	2	5	10	2	10	0	2	14	2	
300	2	10	0	2	16	3	3	2	6	3	8	9	3	15	0	4	1	3	
400	3	6	8	3	15	0	4	3	4	4	11	8	5	0	0	5	8	4	
500	4	3	4	4	13	9	5	4	2	5	14	7	6	5	0	6	15	5	
600	5	0	0	5	12	6	6	5	0	6	17	6	7	10	0	8	2	6	
700	5	16	8	6	11	3	7	5	10	8	0	5	8	15	0	9	9	7	1
800	6	13	4	7	10	0	8	6	8	9	3	4	10	0	0	10	16	8	1
900	7	10	0	8	8	9	9	7	6	10	6	3	11	5	0	12	3	9	1
1000	8	6	8	9	7	6	10	8	4	11	9	2	12	10	0	13	10	10	1
2000	16	13	4	18	15	0	20	16	8	22	18	4	25	0	0	27	1	8	2
3000	25	0	0	28	2	6	31	5	0	34	7	6	37	10	0	40	12	6	4
4000	33	6	8	37	10	0	41	13	4	45	16	8	50	0	0	54	3	4	5
5000	41	13	4	46	17	6	52	1	8	57	5	10	62	10	0	67	14	2	7
6000	50	0	0	56	5	0	62	10	0	68	15	0	75	0	0	81	5	0	8
7000	58	6	8	65	12	6	72	18	4	80	4	2	87	10	0	94	15	10	10
8000	66	13	4	75	0	0	83	6	8	91	13	4	100	0	0	108	6	8	11
9000	75	0	0	84	7	6	93	15	0	103	2	6	112	10	0	121	17	6	13

MONEY TABLE—CONTINUED.

No.	L.	S.	D.	L.	S.	D	L.	S.	D.	L.	S.	D.	L.	S.	D.	L.	S.	D.	L.	S.	D.
	at 3¾d.			at 4d.			at 4¼d.			at 4½d.			at 4¾d.			at 5d.			at 5¼d.		
2	0	0	7½	0	0	8	0	0	8½	0	0	9	0	0	9½	0	0	10	0	0	10
3	0	0	11¼	0	1	0	0	1	0¾	0	1	1½	0	1	2¼	0	1	3	0	1	3
4	0	1	3	0	1	4	0	1	5	0	1	6	0	1	7	0	1	8	0	1	9
5	0	1	6¾	0	1	8	0	1	9¼	0	1	10½	0	1	11¾	0	2	1	0	2	2
6	0	1	10½	0	2	0	0	2	1½	0	2	3	0	2	4½	0	2	6	0	2	7
7	0	2	2¼	0	2	4	0	2	5¾	0	2	7½	0	2	9¼	0	2	11	0	3	0
8	0	2	6	0	2	8	0	2	10	0	3	0	0	3	2	0	3	4	0	3	6
9	0	2	9¾	0	3	0	0	3	2¼	0	3	4½	0	3	6¾	0	3	9	0	3	11
10	0	3	1½	0	3	4	0	3	6½	0	3	9	0	3	11½	0	4	2	0	4	4
11	0	3	5¼	0	3	8	0	3	10¾	0	4	1½	0	4	4¼	0	4	7	0	4	9
12	0	3	9	0	4	0	0	4	3	0	4	6	0	4	9	0	5	0	0	5	3
13	0	4	0¾	0	4	4	0	4	7¼	0	4	10½	0	5	1¾	0	5	5	0	5	8
14	0	4	4½	0	4	8	0	4	11½	0	5	3	0	5	6½	0	5	10	0	6	1
15	0	4	8¼	0	5	0	0	5	3¾	0	5	7½	0	5	11¼	0	6	3	0	6	6
16	0	5	0	0	5	4	0	5	8	0	6	0	0	6	4	0	6	8	0	7	0
17	0	5	3¾	0	5	8	0	6	0¼	0	6	4½	0	6	8¾	0	7	1	0	7	5
18	0	5	7½	0	6	0	0	6	4½	0	6	9	0	7	1½	0	7	6	0	7	10
19	0	5	11¼	0	6	4	0	6	8¾	0	7	1½	0	7	6¼	0	7	11	0	8	3
20	0	6	3	0	6	8	0	7	1	0	7	6	0	7	11	0	8	4	0	8	9
30	0	9	4½	0	10	0	0	10	7½	0	11	3	0	11	10½	0	12	6	0	13	1
40	0	12	6	0	13	4	0	14	2	0	15	0	0	15	10	0	16	8	0	17	6
50	0	15	7½	0	16	8	0	17	8½	0	18	9	0	19	9½	1	0	10	1	1	10
60	0	18	9	1	0	0	1	1	3	1	2	6	1	3	9	1	5	0	1	6	3
70	1	1	10½	1	3	4	1	4	9½	1	6	3	1	7	8½	1	9	2	1	10	7
80	1	5	0	1	6	8	1	8	4	1	10	0	1	11	8	1	13	4	1	15	0
90	1	8	1½	1	10	0	1	11	10½	1	13	9	1	15	7½	1	17	6	1	19	4
100	1	11	3	1	13	4	1	15	5	1	17	6	1	19	7	2	1	8	2	3	9
200	3	2	6	3	6	8	3	10	10	3	15	0	3	19	2	4	3	4	4	7	6
300	4	13	9	5	0	0	5	6	3	5	12	6	5	18	9	6	5	0	6	11	3
400	6	5	0	6	13	4	7	1	8	7	10	0	7	18	4	8	6	8	8	15	0
500	7	16	3	8	6	8	8	17	1	9	7	6	9	17	11	10	8	4	10	18	9
600	9	7	6	10	0	0	10	12	6	11	5	0	11	17	6	12	10	0	13	2	6
700	10	18	9	11	13	4	12	7	11	13	2	6	13	17	1	14	11	8	15	6	3
800	12	10	0	13	6	8	14	3	4	15	0	0	15	16	8	16	13	4	17	10	0
900	14	1	3	15	0	0	15	18	9	16	17	6	17	16	3	18	15	0	19	13	9
1000	15	12	6	16	13	4	17	14	2	18	15	0	19	15	10	20	16	8	21	17	6
2000	31	5	0	33	6	8	35	8	4	37	10	0	39	11	8	41	13	4	43	15	0
3000	46	17	6	50	0	0	53	2	6	56	5	0	59	7	6	62	10	0	65	12	6
4000	62	10	0	66	13	4	70	16	8	75	0	0	79	3	4	83	6	8	87	10	0
5000	78	2	6	83	6	8	88	10	10	93	15	0	98	19	2	104	3	4	109	7	6
6000	93	15	0	100	0	0	106	5	0	112	10	0	118	15	0	125	0	0	131	5	0
7000	109	7	6	116	13	4	123	19	2	131	5	0	138	10	10	145	16	8	153	2	6
8000	125	0	0	133	6	8	141	13	4	150	0	0	158	6	8	166	13	4	175	0	0
9000	140	12	6	150	0	0	159	7	6	168	15	0	178	2	6	187	10	0	196	17	6

MONEY TABLE—CONTINUED.

No.	at 5½d. L.	S.	D.	at 5¾d. L.	S.	D.	at 6d. L.	S.	D.	at 6¼d. L.	S.	D.	at 6½d. L.	S.	D.	at 6¾ L.	S.
2	0	0	11	0	0	11½	0	1	0	0	1	0½	0	1	1	0	1
3	0	1	4½	0	1	5¼	0	1	6	0	1	6¾	0	1	7½	0	1
4	0	1	10	0	1	11	0	2	0	0	2	1	0	2	2	0	2
5	0	2	3½	0	2	4¾	0	2	6	0	2	7¼	0	2	8½	0	2
6	0	2	9	0	2	10½	0	3	0	0	3	1½	0	3	3	0	3
7	0	3	2½	0	3	4¼	0	3	6	0	3	7¾	0	3	9½	0	3
8	0	3	8	0	3	10	0	4	0	0	4	2	0	4	4	0	4
9	0	4	1½	0	4	3¾	0	4	6	0	4	8¼	0	4	10½	0	5
10	0	4	7	0	4	9½	0	5	0	0	5	2½	0	5	5	0	5
11	0	5	0½	0	5	3¼	0	5	6	0	5	8¾	0	5	11½	0	6
12	0	5	6	0	5	9	0	6	0	0	6	3	0	6	6	0	6
13	0	5	11½	0	6	2¾	0	6	6	0	6	9¼	0	7	0½	0	7
14	0	6	5	0	6	8½	0	7	0	0	7	3½	0	7	7	0	7
15	0	6	10½	0	7	2¼	0	7	6	0	7	9¾	0	8	1½	0	8
16	0	7	4	0	7	8	0	8	0	0	8	4	0	8	8	0	9
17	0	7	9½	0	8	1¾	0	8	6	0	8	10¼	0	9	2½	0	9
18	0	8	3	0	8	7½	0	9	0	0	9	4½	0	9	9	0	10
19	0	8	8½	0	9	1¼	0	9	6	0	9	10¾	0	10	3½	0	10
20	0	9	2	0	9	7	0	10	0	0	10	5	0	10	10	0	11
30	0	13	9	0	14	4½	0	15	0	0	15	7½	0	16	3	0	16
40	0	18	4	0	19	2	1	0	0	1	0	10	1	1	8	1	2
50	1	2	11	1	3	11½	1	5	0	1	6	0½	1	7	1	1	8
60	1	7	6	1	8	9	1	10	0	1	11	3	1	12	6	1	13
70	1	12	1	1	13	6½	1	15	0	1	16	5½	1	17	11	1	19
80	1	16	8	1	18	4	2	0	0	2	1	8	2	3	4	2	5
90	2	1	3	2	3	1½	2	5	0	2	6	10½	2	8	9	2	10
100	2	5	10	2	7	11	2	10	0	2	12	1	2	14	2	2	16
200	4	11	8	4	15	10	5	0	0	5	4	2	5	8	4	5	12
300	6	17	6	7	3	9	7	10	0	7	16	3	8	2	6	8	8
400	9	3	4	9	11	8	10	0	0	10	8	4	10	16	8	11	5
500	11	9	2	11	19	7	12	10	0	13	0	5	13	10	10	14	1
600	13	15	0	14	7	6	15	0	0	15	12	6	16	5	0	16	17
700	16	0	10	16	15	5	17	10	0	18	4	7	18	19	2	19	13
800	18	6	8	19	3	4	20	0	0	20	16	8	21	13	4	22	10
900	20	12	6	21	11	3	22	10	0	23	8	9	24	7	6	25	6
1000	22	18	4	23	19	2	25	0	0	26	0	10	27	1	8	28	2
2000	45	16	8	47	18	4	50	0	0	52	1	8	54	3	4	56	5
3000	68	15	0	71	17	6	75	0	0	78	2	6	81	5	0	84	7
4000	91	13	4	95	16	8	100	0	0	104	3	4	108	6	8	112	10
5000	114	11	8	119	15	10	125	0	0	130	4	2	135	8	4	140	12
6000	137	10	0	143	15	0	150	0	0	156	5	0	162	10	0	168	15
7000	160	8	4	167	14	2	175	0	0	182	5	10	189	11	8	196	17
8000	183	6	8	191	13	4	200	0	0	208	6	8	216	13	4	225	0
9000	206	5	0	215	12	6	225	0	0	234	7	6	243	15	0	253	2

MONEY TABLE—CONTINUED.

D.	L.	S.	D.	L.	S.	D.	L.	S.	D.	L.	S.	D.	L.	S.	D.	L.	S.	D.
l.	at 7½d.			at 7¾d.			at 8d.			at 8¼d.			at 8½d.			at 8¾d.		
2½	0	1	3	0	1	3½	0	1	4	0	1	4½	0	1	5	0	1	5½
9¾	0	1	10½	0	1	11¼	0	2	0	0	2	0¾	0	2	1½	0	2	2¼
5	0	2	6	0	2	7	0	2	8	0	2	9	0	2	10	0	2	11
0¼	0	3	1½	0	3	2¾	0	3	4	0	3	5¼	0	3	6½	0	3	7¾
7½	0	3	9	0	3	10½	0	4	0	0	4	1½	0	4	3	0	4	4½
2¾	0	4	4½	0	4	6¼	0	4	8	0	4	9¾	0	4	11½	0	5	1¼
10	0	5	0	0	5	2	0	5	4	0	5	6	0	5	8	0	5	10
5¼	0	5	7½	0	5	9¾	0	6	0	0	6	2¼	0	6	4½	0	6	6¾
0½	0	6	3	0	6	5½	0	6	8	0	6	10½	0	7	1	0	7	3½
7¾	0	6	10½	0	7	1¼	0	7	4	0	7	6¾	0	7	9½	0	8	0¼
3	0	7	6	0	7	9	0	8	0	0	8	3	0	8	6	0	8	9
10¼	0	8	1½	0	8	4¾	0	8	8	0	8	11¼	0	9	2½	0	9	5¾
5½	0	8	9	0	9	0½	0	9	4	0	9	7½	0	9	11	0	10	2½
0¾	0	9	4½	0	9	8¼	0	10	0	0	10	3¾	0	10	7½	0	10	11¼
8	0	10	0	0	10	4	0	10	8	0	11	0	0	11	4	0	11	8
3¼	0	10	7½	0	10	11¾	0	11	4	0	11	8¼	0	12	0½	0	12	4¾
10½	0	11	3	0	11	7½	0	12	0	0	12	4½	0	12	9	0	13	1½
5¾	0	11	10½	0	12	3¼	0	12	8	0	13	0¾	0	13	5½	0	13	10¼
1	0	12	6	0	12	11	0	13	4	0	13	9	0	14	2	0	14	7
1½	0	18	9	0	19	4½	1	0	0	1	0	7½	1	1	3	1	1	10½
2	1	5	0	1	5	10	1	6	8	1	7	6	1	8	4	1	9	2
2½	1	11	3	1	12	3½	1	13	4	1	14	4½	1	15	5	1	16	5½
3	1	17	6	1	18	9	2	0	0	2	1	3	2	2	6	2	3	9
3½	2	3	9	2	5	2½	2	6	8	2	8	1½	2	9	7	2	11	0½
4	2	10	0	2	11	8	2	13	4	2	15	0	2	16	8	2	18	4
4½	2	16	3	2	18	1½	3	0	0	3	1	10½	3	3	9	3	5	7½
5	3	2	6	3	4	7	3	6	8	3	8	9	3	10	10	3	12	11
10	6	5	0	6	9	2	6	13	4	6	17	6	7	1	8	7	5	10
3	9	7	6	9	13	9	10	0	0	10	6	3	10	12	6	10	18	9
8	12	10	0	12	18	4	13	6	8	13	15	0	14	3	4	14	11	8
1	15	12	6	16	2	11	16	13	4	17	3	9	17	14	2	18	4	7
6	18	15	0	19	7	6	20	0	0	20	12	6	21	5	0	21	17	6
11	21	17	6	22	12	1	23	6	8	24	1	3	24	15	10	25	10	5
4	25	0	0	25	16	8	26	13	4	27	10	0	28	6	8	29	3	4
9	28	2	6	29	1	3	30	0	0	30	18	9	31	17	6	32	16	3
2	31	5	0	32	5	10	33	6	8	34	7	6	35	8	4	36	9	2
4	62	10	0	64	11	8	66	13	4	68	15	0	70	16	8	72	18	4
6	93	15	0	96	17	6	100	0	0	103	2	6	106	5	0	109	7	6
8	125	0	0	129	3	4	133	6	8	137	10	0	141	13	4	145	16	8
10	156	5	0	161	9	2	166	13	4	171	17	6	177	1	8	182	5	10
0	187	10	0	193	15	0	200	0	0	206	5	0	212	10	0	218	15	0
2	218	15	0	226	0	10	233	6	8	240	12	6	247	18	4	255	4	2
4	250	0	0	258	6	8	266	13	4	275	0	0	283	6	8	291	13	4
6	281	5	0	290	12	6	300	0	0	309	7	6	318	15	0	328	2	6

MONEY TABLE—CONTINUED.

No.	at 9d. L.	S.	D.	at 9¼d. L.	S.	D.	at 9½d. L.	S.	D.	at 9¾d. L.	S.	D.	at 10d. L.	S.	D.	at 10¼d. L.	S.	D.
2	0	1	6	0	1	6½	0	1	7	0	1	7½	0	1	8	0	1	8
3	0	2	3	0	2	3¾	0	2	4½	0	2	5¼	0	2	6	0	2	6
4	0	3	0	0	3	1	0	3	2	0	3	3	0	3	4	0	3	5
5	0	3	9	0	3	10¼	0	3	11½	0	4	0¾	0	4	2	0	4	3
6	0	4	6	0	4	7½	0	4	9	0	4	10½	0	5	0	0	5	1
7	0	5	3	0	5	4¾	0	5	6½	0	5	8¼	0	5	10	0	5	11
8	0	6	0	0	6	2	0	6	4	0	6	6	0	6	8	0	6	10
9	0	6	9	0	6	11¼	0	7	1½	0	7	3¾	0	7	6	0	7	8
10	0	7	6	0	7	8½	0	7	11	0	8	1½	0	8	4	0	8	6
11	0	8	3	0	8	5¾	0	8	8½	0	8	11¼	0	9	2	0	9	4
12	0	9	0	0	9	3	0	9	6	0	9	9	0	10	0	0	10	3
13	0	9	9	0	10	0¼	0	10	3½	0	10	6¾	0	10	10	0	11	1
14	0	10	6	0	10	9½	0	11	1	0	11	4½	0	11	8	0	11	11
15	0	11	3	0	11	6¾	0	11	10½	0	12	2¼	0	12	6	0	12	9
16	0	12	0	0	12	4	0	12	8	0	13	0	0	13	4	0	13	8
17	0	12	9	0	13	1¼	0	13	5½	0	13	9¾	0	14	2	0	14	6
18	0	13	6	0	13	10½	0	14	3	0	14	7½	0	15	0	0	15	4
19	0	14	3	0	14	7¾	0	15	0½	0	15	5¼	0	15	10	0	16	2
20	0	15	0	0	15	5	0	15	10	0	16	3	0	16	8	0	17	1
30	1	2	6	1	3	1½	1	3	9	1	4	4½	1	5	0	1	5	7
40	1	10	0	1	10	10	1	11	8	1	12	6	1	13	4	1	14	2
50	1	17	6	1	18	6½	1	19	7	2	0	7½	2	1	8	2	2	8
60	2	5	0	2	6	3	2	7	6	2	8	9	2	10	0	2	11	3
70	2	12	6	2	13	11½	2	15	5	2	16	10½	2	18	4	2	19	9
80	3	0	0	3	1	8	3	3	4	3	5	0	3	6	8	3	8	4
90	3	7	6	3	9	4½	3	11	3	3	13	1½	3	15	0	3	16	10
100	3	15	0	3	17	1	3	19	2	4	1	3	4	3	4	4	5	5
200	7	10	0	7	14	2	7	18	4	8	2	6	8	6	8	8	10	10
300	11	5	0	11	11	3	11	17	6	12	3	9	12	10	0	12	16	3
400	15	0	0	15	8	4	15	16	8	16	5	0	16	13	4	17	1	8
500	18	15	0	19	5	5	19	15	10	20	6	3	20	16	8	21	7	1
600	22	10	0	23	2	6	23	15	0	24	7	6	25	0	0	25	12	6
700	26	5	0	26	19	7	27	14	2	28	8	9	29	3	4	29	17	11
800	30	0	0	30	16	8	31	13	4	32	10	0	33	6	8	34	3	4
900	33	15	0	34	13	9	35	12	6	36	11	3	37	10	0	38	8	9
1000	37	10	0	38	10	10	39	11	8	40	12	6	41	13	4	42	14	2
2000	75	0	0	77	1	8	79	3	4	81	5	0	83	6	8	85	8	4
3000	112	10	0	115	12	6	118	15	0	121	17	6	125	0	0	128	2	6
4000	150	0	0	154	3	4	158	6	8	162	10	0	166	13	4	170	16	8
5000	187	10	0	192	14	2	197	18	4	203	2	6	208	6	8	213	10	10
6000	225	0	0	231	5	0	237	10	0	243	15	0	250	0	0	256	5	0
7000	262	10	0	269	15	10	277	1	8	284	7	6	291	13	4	298	19	2
8000	300	0	0	308	6	8	316	13	4	325	0	0	333	6	8	341	13	4
9000	337	10	0	346	17	6	356	5	0	365	12	6	375	0	0	384	7	6

MONEY TABLE—CONTINUED.

No.	L.	S.	D.	L.	S.	D.	L.	S.	D.	L.	S.	D.	L.	S.	D.	L.	S.	D.
	at 10¾d.			at 11d.			at 11¼d.			at 11½d.			at 11¾d.			at 1s.		
2	0	1	9½	0	1	10	0	1	10½	0	1	11	0	1	11½	0	2	0
3	0	2	8¼	0	2	9	0	2	9¾	0	2	10½	0	2	11¼	0	3	0
4	0	3	7	0	3	8	0	3	9	0	3	10	0	3	11	0	4	0
5	0	4	5¾	0	4	7	0	4	8¼	0	4	9½	0	4	10¾	0	5	0
6	0	5	4½	0	5	6	0	5	7½	0	5	9	0	5	10½	0	6	0
7	0	6	3¼	0	6	5	0	6	6¾	0	6	8½	0	6	10¼	0	7	0
8	0	7	2	0	7	4	0	7	6	0	7	8	0	7	10	0	8	0
9	0	8	0¾	0	8	3	0	8	5¼	0	8	7½	0	8	9¾	0	9	0
10	0	8	11½	0	9	2	0	9	4½	0	9	7	0	9	9½	0	10	0
11	0	9	10¼	0	10	1	0	10	3¾	0	10	6½	0	10	9¼	0	11	0
12	0	10	9	0	11	0	0	11	3	0	11	6	0	11	9	0	12	0
13	0	11	7¾	0	11	11	0	12	2¼	0	12	5½	0	12	8¾	0	13	0
14	0	12	6½	0	12	10	0	13	1½	0	13	5	0	13	8½	0	14	0
15	0	13	5¼	0	13	9	0	14	0¾	0	14	4½	0	14	8¼	0	15	0
16	0	14	4	0	14	8	0	15	0	0	15	4	0	15	8	0	16	0
17	0	15	2¾	0	15	7	0	15	11¼	0	16	3½	0	16	7¾	0	17	0
18	0	16	1½	0	16	6	0	16	10½	0	17	3	0	17	7½	0	18	0
19	0	17	0¼	0	17	5	0	17	9¾	0	18	2½	0	18	7¼	0	19	0
20	0	17	11	0	18	4	0	18	9	0	19	2	0	19	7	1	0	0
30	1	6	10½	1	7	6	1	8	1½	1	8	9	1	9	4½	1	10	0
40	1	15	10	1	16	8	1	17	6	1	18	4	1	19	2	2	0	0
50	2	4	9½	2	5	10	2	6	10½	2	7	11	2	8	11½	2	10	0
60	2	13	9	2	15	0	2	16	3	2	17	6	2	18	9	3	0	0
70	3	2	8½	3	4	2	3	5	7½	3	7	1	3	8	6½	3	10	0
80	3	11	8	3	13	4	3	15	0	3	16	8	3	18	4	4	0	0
90	4	0	7½	4	2	6	4	4	4½	4	6	3	4	8	1½	4	10	0
100	4	9	7	4	11	8	4	13	9	4	15	10	4	17	11	5	0	0
200	8	19	2	9	3	4	9	7	6	9	11	8	9	15	10	10	0	0
300	13	8	9	13	15	0	14	1	3	14	7	6	14	13	9	15	0	0
400	17	18	4	18	6	8	18	15	0	19	3	4	19	11	8	20	0	0
500	22	7	11	22	18	4	23	8	9	23	19	2	24	9	7	25	0	0
600	26	17	6	27	10	0	28	2	6	28	15	0	29	7	6	30	0	0
700	31	7	1	32	1	8	32	16	3	33	10	10	34	5	5	35	0	0
800	35	16	8	36	13	4	37	10	0	38	6	8	39	3	4	40	0	0
900	40	6	3	41	5	0	42	3	9	43	2	6	44	1	3	45	0	0
1000	44	15	10	45	16	8	46	17	6	47	18	4	48	19	2	50	0	0
2000	89	11	8	91	13	4	93	15	0	95	16	8	97	18	4	100	0	0
3000	134	7	6	137	10	0	140	12	6	143	15	0	146	17	6	150	0	0
4000	179	3	4	183	6	8	187	10	0	191	13	4	195	16	8	200	0	0
5000	223	19	2	229	3	4	234	7	6	239	11	8	244	15	10	250	0	0
6000	268	15	0	275	0	0	281	5	0	287	10	0	293	15	0	300	0	0
7000	313	10	10	320	16	8	328	2	6	335	8	4	342	14	2	350	0	0
8000	358	6	8	366	13	4	375	0	0	383	6	8	391	13	4	400	0	0
9000	403	2	6	412	10	0	421	17	6	431	5	0	440	12	6	450	0	0

EQUIVALENT PRICES TO COMMON WEIGHTS AND NUMBERS.

Per ton or 2240 lbs.			cwt. or 112 lbs.			qr. or 28 lbs.			stone or 14 lbs.		lb. or 1.	doz. or 12.		score or 20.		per 100.			per 120.			gross or 144.			per 1000.		
L.	S.	D.	L.	S.	D.	L.	S.	D.	S.	D.	D.	S.	D.	S.	D.	L.	S.	D.	L.	S.	D.	L.	S.	D.	L.	S.	D.
2	6	8	0	2	4	0	0	7	0	3½	¼	0	3	0	5	0	2	1	0	2	6	0	3	0	1	0	10
3	10	0	0	3	6	0	0	10½	0	5¼	⅜	0	4½	0	7½	0	3	1½	0	3	9	0	4	6	1	11	3
4	13	4	0	4	8	0	1	2	0	7	½	0	6	0	10	0	4	2	0	5	0	0	6	0	2	1	8
5	16	8	0	5	10	0	1	5½	0	8¾	⅝	0	7½	1	0½	0	5	2½	0	6	3	0	7	6	2	12	1
7	0	0	0	7	0	0	1	9	0	10½	¾	0	9	1	3	0	6	3	0	7	6	0	9	0	3	2	6
8	3	4	0	8	2	0	2	0½	1	0¼	⅞	0	10½	1	5½	0	7	3½	0	8	9	0	10	6	3	12	11
9	6	8	0	9	4	0	2	4	1	2	1d.	1	0	1	8	0	8	4	0	10	0	0	12	0	4	3	4
10	10	0	0	10	6	0	2	7½	1	3¾	1⅛	1	1½	1	10½	0	9	4½	0	11	3	0	13	6	4	13	9
11	13	4	0	11	8	0	2	11	1	5½	1¼	1	3	2	1	0	10	5	0	12	6	0	15	0	5	4	2
12	16	8	0	12	10	0	3	2½	1	7¼	1⅜	1	4½	2	3½	0	11	5½	0	13	9	0	16	6	5	14	7
14	0	0	0	14	0	0	3	6	1	9	1½	1	6	2	6	0	12	6	0	15	0	0	18	0	6	5	0
15	3	4	0	15	2	0	3	9½	1	10¾	1⅝	1	7½	2	8½	0	13	6½	0	16	3	0	19	6	6	15	5
16	6	8	0	16	4	0	4	1	2	0½	1¾	1	9	2	11	0	14	7	0	17	6	1	1	0	7	5	10
17	10	0	0	17	6	0	4	4½	2	2¼	1⅞	1	10½	3	1½	0	15	7½	0	18	9	1	2	6	7	16	3
18	13	4	0	18	8	0	4	8	2	4	2d.	2	0	3	4	0	16	8	1	0	0	1	4	0	8	6	8
19	16	8	0	19	10	0	4	11½	2	5¾	2⅛	2	1½	3	6½	0	17	8½	1	1	3	1	5	6	8	17	1
21	0	0	1	1	0	0	5	3	2	7½	2¼	2	3	3	9	0	18	9	1	2	6	1	7	0	9	7	6
22	3	4	1	2	2	0	5	6½	2	9¼	2⅜	2	4½	3	11½	0	19	9½	1	3	9	1	8	6	9	17	11
23	6	8	1	3	4	0	5	10	2	11	2½	2	6	4	2	1	0	10	1	5	0	1	10	0	10	8	4
24	10	0	1	4	6	0	6	1½	3	0¾	2⅝	2	7½	4	4½	1	1	10½	1	6	3	1	11	6	10	18	9
25	13	4	1	5	8	0	6	5	3	2½	2¾	2	9	4	7	1	2	11	1	7	6	1	13	0	11	9	2
26	16	8	1	6	10	0	6	8½	3	4¼	2⅞	2	10½	4	9½	1	3	11½	1	8	9	1	14	6	11	19	7
28	0	0	1	8	0	0	7	0	3	6	3d.	3	0	5	0	1	5	0	1	10	0	1	16	0	12	10	0
29	3	4	1	9	2	0	7	3½	3	7¾	3⅛	3	1½	5	2½	1	6	0½	1	11	3	1	17	6	13	0	5
30	6	8	1	10	4	0	7	7	3	9½	3¼	3	3	5	5	1	7	1	1	12	6	1	19	0	13	10	10
31	10	0	1	11	6	0	7	10½	3	11¼	3⅜	3	4½	5	7½	1	8	1½	1	13	9	2	0	6	14	1	3
32	13	4	1	12	8	0	8	2	4	1	3½	3	6	5	10	1	9	2	1	15	0	2	2	0	14	11	8
33	16	8	1	13	4	0	8	5½	4	2¾	3⅝	3	7½	6	0½	1	10	2½	1	16	3	2	3	6	15	2	1
35	0	0	1	15	0	0	8	9	4	4½	3¾	3	9	6	3	1	11	3	1	17	6	2	5	0	15	12	6
36	3	4	1	16	2	0	9	0½	4	6¼	3⅞	3	10½	6	5½	1	12	3½	1	18	9	2	6	6	16	2	11
37	6	8	1	17	4	0	9	4	4	8	4d.	4	0	6	8	1	13	4	2	0	0	2	8	0	16	13	4

38	10	0	1	18	6	0	9	7½	4	9¾	4⅛	4	1½	6	10½	1	14	4½	2	1	3	2	9	6	17	3	9
39	13	4	1	19	8	0	9	11	4	11½	4¼	4	3	7	1	1	15	5	2	2	6	2	11	0	17	14	2
40	16	8	2	0	10	0	10	2½	5	1¼	4⅜	4	4½	7	3½	1	16	5½	2	3	9	2	12	6	18	4	7
42	0	0	2	2	0	0	10	6	5	3	4½	4	6	7	6	1	17	6	2	5	0	2	14	0	18	15	0
43	3	4	2	3	2	0	10	9½	5	4¾	4⅝	4	7½	7	8½	1	18	6½	2	6	3	2	15	6	19	5	5
44	6	8	2	4	4	0	11	1	5	6½	4¾	4	9	7	11	1	19	7	2	7	6	2	17	0	19	15	10
45	10	0	2	5	6	0	11	4½	5	8¼	4⅞	4	10½	8	1½	2	0	7½	2	8	9	2	18	6	20	6	3
46	13	4	2	6	8	0	11	8	5	10	5d.	5	0	8	4	2	1	8	2	10	0	3	0	0	20	16	8
49	0	0	2	9	0	0	12	3	6	1½	5¼	5	3	8	9	2	3	9	2	12	6	3	3	0	21	17	6
51	6	8	2	11	4	0	12	10	6	5	5½	5	6	9	2	2	5	10	2	15	0	3	6	0	22	18	4
53	13	4	2	13	8	0	13	5	6	8½	5¾	5	9	9	7	2	7	11	2	17	6	3	9	0	23	19	2
56	0	0	2	16	0	0	14	0	7	0	6d.	6	0	10	0	2	10	0	3	0	0	3	12	0	25	0	0
58	6	8	2	18	4	0	14	7	7	3½	6¼	6	3	10	5	2	12	1	3	2	6	3	15	0	26	0	10
60	13	4	3	0	8	0	15	2	7	7	6½	6	6	10	10	2	14	2	3	5	0	3	18	0	27	1	8
63	0	0	3	3	0	0	15	9	7	10½	6¾	6	9	11	3	2	16	3	3	7	6	4	1	0	28	2	6
65	6	8	3	5	4	0	16	4	8	2	7d.	7	0	11	8	2	18	4	3	10	0	4	4	0	29	3	4
67	13	4	3	7	8	0	16	11	8	5½	7¼	7	3	12	1	3	0	5	3	12	6	4	7	0	30	4	2
70	0	0	3	10	0	0	17	6	8	9	7½	7	6	12	6	3	2	6	3	15	0	4	10	0	31	5	0
72	6	8	3	12	4	0	18	1	9	0½	7¾	7	9	12	11	3	4	7	3	17	6	4	13	0	32	5	10
74	13	4	3	14	8	0	18	8	9	4	8d.	8	0	13	4	3	6	8	4	0	0	4	16	0	33	6	8
77	0	0	3	17	0	0	19	3	9	7½	8¼	8	3	13	9	3	8	9	4	2	6	4	19	0	34	7	6
79	6	8	3	19	4	0	19	10	9	11	8½	8	6	14	2	3	10	10	4	5	0	5	2	0	35	8	4
81	13	4	4	1	8	1	0	5	10	2½	8¾	8	9	14	7	3	12	11	4	7	6	5	5	0	36	9	2
84	0	0	4	4	0	1	1	0	10	6	9d.	9	0	15	0	3	15	0	4	10	0	5	8	0	37	10	0
86	6	8	4	6	4	1	1	7	10	9½	9¼	9	3	15	5	3	17	1	4	12	6	5	11	0	38	10	10
88	13	4	4	8	8	1	2	2	11	1	9½	9	6	15	10	3	19	2	4	15	0	5	14	0	39	11	8
91	0	0	4	11	0	1	2	9	11	4½	9¾	9	9	16	3	4	1	3	4	17	6	5	17	0	40	12	6
93	6	8	4	13	4	1	3	4	11	8	10d.	10	0	16	8	4	3	4	5	0	0	6	0	0	41	13	4
95	13	4	4	15	8	1	3	11	11	11½	10¼	10	3	17	1	4	5	5	5	2	6	6	3	0	42	14	2
98	0	0	4	18	0	1	4	6	12	3	10½	10	6	17	6	4	7	6	5	5	0	6	6	0	43	15	0
100	6	8	5	0	4	1	5	1	12	6½	10¾	10	9	17	11	4	9	7	5	7	6	6	9	0	44	15	10
102	13	4	5	2	8	1	5	8	12	10	11d.	11	0	18	4	4	11	8	5	10	0	6	12	0	45	16	8
105	0	0	5	5	0	1	6	3	13	1½	11¼	11	3	18	9	4	13	9	5	12	6	6	15	0	46	17	6
107	6	8	5	7	4	1	6	10	13	5	11½	11	6	19	2	4	15	10	5	15	0	6	18	0	47	18	4
109	13	4	5	9	8	1	7	5	13	8½	11¾	11	9	19	7	4	17	11	5	17	6	7	1	0	48	19	2
112	0	0	5	12	0	1	8	0	14	0	12d.	12	0	20	0	5	0	0	6	0	0	7	4	0	50	0	0

Practical Utility of the preceding Table

1. What will be the cost of 1 ton 2 cwts. 3 qr at $7\frac{3}{4}$ per lb.

1 ton	=	2240 lbs.	
2 cwts.	=	224	„
3 qrs.	=	84	„
4 lbs.	=	4	„
Total	=	2552	„

And 2000 at $7\frac{3}{4}d.$ (as per Table, p. 131)	=	£64	11	
500	„	=	16	2
50	„	=	1	12
2	„	=	0	1
2552			£82	8

2. In the Table of Equivalent Prices, the f lumn from the left hand is the price per single or 1; hence the other columns on the right an that give the price at an equal rate, according various denominations by which the columns are l

Thus, suppose the price per lb. $=3\frac{1}{4}d.$, the p ton $=$ £30. 6*s.* 8*d.* Again, suppose the price p $=$ £1. 10*s.*, the price per dozen $=2s.$ 6*d.*, &c.

STRENGTH OF MATERIALS.

MATERIALS of construction are liable to fo ferent kinds of strain; viz., stretching, cr transverse action, and torsion or twisting: t of which depends upon the body's tenacity the second, on its resistance to compression; th on its tenacity and compression combined; a fourth, on that property by which it oppos acting force tending to change from a straig to that of a spiral direction, the fibres of whi body is composed.

In bodies, the power of tenacity and resista

compression in the direction of their length, is as the cross section of their area multiplied by the results of experiments on similar bodies, as exhibited in the following Table.

Table showing the Tenacities, Resistances to Compression, and other Properties of the common Materials of Construction.

Names of Bodies.	Absolute		Compared with Cast Iron		
	Tenacity in lbs. per sq. inch.	Resistance to compression in lbs. per sq. in.	Its strength is	Its extensibility is	Its stiffness is
Ash . . .	14130	—	0·23	2·6	0·089
Beech . . .	12225	8548	0·15	2·1	0·073
Brass . . .	17968	10304	0·435	0·9	0·49
Brick . . .	275	562	—	—	—
Cast iron . . .	13434	86397	1·000	1·0	1·000
Copper (wrought) .	33000	—	—	—	—
Elm . . .	9720	1033	0·21	2·9	0·073
Fir, or Pine, white .	12346	2028	0·23	2·4	0·1
„ „ red .	11800	5375	0·3	2·4	0·1
„ „ yellow .	11835	5445	0·25	2·9	0·087
Granite, Aberdeen .	—	10910	—	—	—
Gun-metal (copper 8, and tin 1) . .	35838	—	0·65	1·25	0·535
Malleable iron . .	56000	—	1·12	0·86	1·3
Larch . . .	12240	5568	0·136	2·3	0·058
Lead . . .	1824	—	0·096	2·5	0·0385
Mahogany, Honduras	11475	8000	0·24	2·9	0·487
Marble . . .	551	6060	—	—	—
Oak	11880	9504	0·25	2·8	0·093
Rope (1 in. in circum.)	200	—	—	—	—
Steel . . .	128000	—	—	—	—
Stone, Bath . .	478	—	—	—	—
„ Craigleith .	772	5490	—	—	—
„ Dundee . .	2661	6630	—	—	—
„ Portland .	857	3729	—	—	—
Tin (cast) . .	4736	—	0·182	0·75	0·25
Zinc (sheet) . .	9120	—	0·365	0·5	0·76

Comparative Strength and Weight of Rope Chains.

Circum. of rope in inches.	Weight per fathom in lbs.	Diameter of chain in inches.	Weight per fathom in lbs.	Proof strength in tons & cwt.		Circum. of rope in inches.	Weight per fathom in lbs.	Diameter of chain in inches.	Weight per fathom in lbs.
$3\frac{1}{2}$	$2\frac{3}{4}$	$\frac{5}{16}$	$5\frac{1}{2}$	1	$5\frac{1}{2}$	10	23	$\frac{7}{8}$	43
$4\frac{1}{4}$	$4\frac{3}{4}$	$\frac{3}{8}$	8	1	$16\frac{3}{4}$	$10\frac{3}{4}$	28	$\frac{15}{16}$	49
5	$5\frac{3}{4}$	$\frac{7}{16}$	$10\frac{1}{2}$	2	10	$11\frac{1}{2}$	$30\frac{1}{2}$	1 in.	56
$5\frac{3}{4}$	7	$\frac{1}{2}$	14	3	$5\frac{1}{2}$	$12\frac{1}{4}$	36	$1\frac{1}{16}$	63
$6\frac{1}{2}$	$9\frac{3}{4}$	$\frac{9}{16}$	18	4	$3\frac{1}{2}$	13	39	$1\frac{1}{8}$	71
7	$11\frac{1}{4}$	$\frac{5}{8}$	22	5	2	$13\frac{3}{4}$	45	$1\frac{3}{16}$	79
8	15	$\frac{11}{16}$	27	6	$4\frac{1}{2}$	$14\frac{1}{2}$	$48\frac{1}{2}$	$1\frac{1}{4}$	87
$8\frac{3}{4}$	19	$\frac{3}{4}$	32	7	7	$15\frac{1}{4}$	56	$1\frac{5}{16}$	96
$9\frac{1}{2}$	21	$\frac{13}{16}$	37	8	$13\frac{1}{2}$	16	60	$1\frac{3}{8}$	106

Note.—It must be understood and also borne in m in estimating the amount of tensile strain to which subjected, the weight of the body itself must also be t account; for according to its position so may it appro its whole weight, in tending to produce tension with as in the almost constant application of ropes and great depths, considerable heights, &c.

Alloys that are of greater Tenacity than the their Constituents, as determined by the ments of Muschenbroek.

Swedish copper 6 parts, Malacca tin 1; tenacity per square inch
Chili copper 6 parts, Malacca tin 1; ,, ,,
Japan copper 5 parts, Banca tin 1; ,, ,,
Anglesea copper 6 parts, Cornish tin 1; ,, ,,
Common block tin 4, lead 1, zinc 1; ,, ,,
Malacca tin 4, regulus of antimony 1; ,, ,,
Block tin 3, lead 1; ,, ,,
Block tin 8, zinc 1; ,, ,,
Lead 1, zinc 1; ,, ,,

RESISTANCE TO LATERAL PRESSURE, OR TRANSVERSE ACTION.

The strength of a square or rectangular beam to resist lateral pressure acting in a perpendicular direction to its length, is as the breadth and square of the depth, and inversely as the length;—thus, a beam twice the breadth of another, all other circumstances being alike, equal twice the strength of the other; or twice the depth, equal four times the strength, and twice the length, equal only half the strength, &c., according to the rule.

Table of Data, containing the Results of Experiments on the Elasticity and Strength of various Species of Timber, by Mr. Barlow.

Species of Timber.	Value of E.	Value of S.	Species of Timber.	Value of E.	Value of S.
Teak . . .	174·7	2462	Elm	50·64	1013
Poona . .	122·26	2221	Pitch pine . .	88·68	1632
English oak .	105	1672	Red pine . . .	133	1341
Canadian do.	155·5	1766	New England fir	158·5	1102
Dantzic do.	86·2	1457	Riga fir . . .	90	1100
Adriatic do.	70·5	1383	Mar Forest do.	63	1200
Ash . . .	119	2026	Larch	76	900
Beech . .	98	1556	Norway spruce .	105·47	1474

To find the dimensions of a beam capable of sustaining a given weight, with a given degree of deflection, when supported at both ends.

Rule.—Multiply the weight to be supported in lbs. by the cube of the length in feet; divide the product by 32 times the tabular value of E, multiplied into the given deflection in inches, and the

quotient is the breadth multiplied by the cube of the depth in inches.

Note 1.—When the beam is intended to be square, then the fourth root of the quotient is the breadth and depth required.

Note 2.—If the beam is to be cylindrical, multiply the quotient by 1·7, and the fourth root of the product is the diameter.

Ex. The distance between the supports of a beam of Riga fir is 16 feet, and the weight it must be capable of sustaining in the middle of its length is 8000 lbs., with a deflection of not more than $\frac{3}{4}$ of an inch; what must be the depth of the beam, supposing the breadth 8 inches?

$$\frac{16 \times 8000}{90 \times 32 \times \cdot 75} = 15175 \div 8 = \sqrt[3]{1897} = 12{\cdot}35 \text{ inches the depth.}$$

To determine the absolute strength of a rectangular beam of timber when supported at both ends, and loaded in the middle of its length, as beams in general ought to be calculated to, so that they may be rendered capable of withstanding all accidental cases of emergency.

Rule.—Multiply the tabular value of s by four times the depth of the beam in inches, and by the area of the cross section in inches; divide the product by the distance between the supports in inches, and the quotient will be the absolute strength of the beam in lbs.

Note 1.—If the beam be not laid horizontally, the distance between the supports, for calculation, must be the horizontal distance.

Note 2.—One-fourth of the weight obtained by the rule is the greatest weight that ought to be applied in practice as permanent load.

Note 3.—If the load is to be applied at any other point than the middle, then the strength will be, as the product of the two distances is to the square of half the length of the beam

between the supports;—or, twice the distance from one end, multiplied by twice from the other, and divided by the whole length, equal the effective length of the beam.

Ex. In a building 18 feet in width, an engine boiler of $5\frac{1}{2}$ tons is to be fixed, the centre of which to be 7 feet from the wall; and having two pieces of red pine 10 inches by 6, which I can lay across the two walls for the purpose of slinging it at each end,—may I with sufficient confidence apply them, so as to effect this object?

$$\frac{2240 \times 5{\cdot}5}{2} = 6160 \text{ lbs. to carry at each end.}$$

And 18 feet $- 7 = 11$, double each, or 14 and 22, then

$$\frac{14 \times 22}{18} = 17 \text{ feet, or 204 inches, effective length of beam.}$$

$$\text{Tabular value of s, red pine} = \frac{1341 \times 4 \times 10 \times 60}{204} = 15776 \text{ lbs.,}$$

the absolute strength of each piece of timber at that point.

To determine the dimensions of a rectangular beam capable of supporting a required weight, with a given degree of deflection, when fixed at one end.

Rule.—Divide the weight to be supported, in lbs., by the tabular value of E, multiplied by the breadth and deflection, both in inches; and the cube root of the quotient, multiplied by the length in feet, equal the depth required in inches.

Ex. A beam of ash is intended to bear a load of 700 lbs. at its extremity; its length being 5 feet, its breadth 4 inches, and the deflection not to exceed $\frac{1}{2}$ an inch.

Tabular value of $\text{E} = 119 \times 4 \times {\cdot}5 = 238$, the divisor;
then $700 \div 238 = \sqrt[3]{2{\cdot}94} \times 5 = 7{\cdot}25$ inches, depth of the beam.

To find the absolute strength of a rectangular

beam, when fixed at one end, and loaded at the other.

Rule.—Multiply the value of s by the depth of the beam, and by the area of its section, both in inches; divide the product by the leverage in inches, and the quotient equal the absolute strength of the beam in lbs.

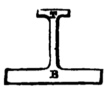
Ex. A beam of Riga fir, 12 inches by $4\frac{1}{2}$, and projecting $6\frac{1}{2}$ feet from the wall; what is the greatest weight it will support at the extremity of its length?

Tabular value of $s = 1100$

$12 \times 4{\cdot}5 = 54$ sectional area,

$$\text{Then, } \frac{1100 \times 12 \times 54}{78} = 9138{\cdot}4 \text{ lbs.}$$

When fracture of a beam is produced by vertical pressure, the fibres of the lower section of fracture are separated by extension, whilst at the same time those of the upper portion are destroyed by compression; hence exists a point in section where neither the one nor the other takes place, and which is distinguished as the point of neutral axis. Therefore, by the law of fracture thus established, and proper data of tenacity and compression given, as in the Table (p. 137), we are enabled to form metal beams of strongest section with the least possible material: thus, in cast iron the resistance to compression is nearly as $6\frac{1}{2}$ to 1 of tenacity; consequently a beam of cast iron to be of strongest section must be of the following form,



and a parabola in the direction of its length, the quantity of material in the bottom flange being about $6\frac{1}{2}$ times that of the upper: but such is not the case with beams of timber; for although the tenacity of timber be on an average twice that of its resistance to *compression*, its flexibility is so great, that any con-

siderable length of beam, where columns cannot be situated to its support, requires to be strengthened or trussed by iron rods, as in the following manner:

And these applications of principle not only tend to diminish deflection, but the required purpose is also more effectively attained, and that by lighter pieces of timber.

To ascertain the absolute strength of a cast-iron beam of the preceding form, or that of strongest section.

Rule.—Multiply the sectional area of the bottom flange in inches by the depth of the beam in inches, and divide the product by the distance between the supports also in inches; and 514 times the quotient equal the absolute strength of the beam in cwts.

The strongest form in which any given quantity of matter can be disposed is that of a hollow cylinder; and it has been demonstrated that the maximum of strength is obtained in cast iron when the thickness of the annulus or ring amounts to $\frac{1}{5}$th of the cylinder's external diameter; the relative strength of a solid to that of a hollow cylinder being as the diameters of their sections.

A Table showing the Weight or Pressure a Beam of 1 inch in breadth, will sustain without destroying force, when it is supported at each end, and loa middle of its length, and also the deflection in the m that weight will produce. By Mr. Hodgkinson, M

Length.	6 feet.		7 feet.		8 feet.		9 feet.	
Depth in in.	Wt. in lbs.	Defl. in in.	Wt. in lbs.	Defl. in in.	Wt. in lbs.	Defl. in in.	Wt. in lbs.	Defl. in in.
3	1278	·24	1089	·33	954	·426	855	·54
3½	1739	·205	1482	·28	1298	·365	1164	·46
4	2272	·18	1936	·245	1700	·32	1520	·405
4½	2875	·16	2450	·217	2146	·284	1924	·36
5	3560	·144	3050	·196	2650	·256	2375	·32
6	5112	·12	4356	·163	3816	·213	3420	·27
7	6958	·103	5929	·14	5194	·183	4655	·23
8	9088	·09	7744	·123	6784	·16	6080	·203
9	—	—	9801	·109	8586	·142	7695	·18
10	—	—	12100	·098	10600	·128	9500	·162
11	—	—	—	—	12826	·117	11495	·15
12	—	—	—	—	15264	·107	13680	·135
13	—	—	—	—	—	—	16100	·125
14	—	—	—	—	—	—	18600	·115
	12 feet.		14 feet.		16 feet.		18 feet.	
6	2548	·48	2184	·65	1912	·85	1699	1·08
7	3471	·41	2975	·58	2603	·73	2314	·93
8	4532	·36	3884	·49	3396	·64	3020	·81
9	5733	·32	4914	·44	4302	·57	3825	·72
10	7083	·28	6071	·39	5312	·51	4722	·64
11	8570	·26	7346	·36	6428	·47	5714	·59
12	10192	·24	8736	·33	7648	·43	6796	·54
13	11971	·22	10260	·31	8978	·39	7980	·49
14	13883	·21	11900	·28	10412	·36	9255	·46
15	15937	·19	13660	·26	11952	·34	10624	·43
16	18128	·18	15536	·24	13584	·32	12080	·40
17	20500	·17	17500	·23	15353	·3	13647	·38
18	22932	·16	19656	·21	17208	·28	15700	·36

Note.—This Table shows the greatest weight that ever oug *upon* a beam for permanent load, and if there be any liability t *ample* allowance must be made; also the weight of the bea *be included.*

To find the weight of a cast-iron beam of given dimensions.

Rule.—Multiply the sectional area in inches by the length in feet, and by 3·2, the product equal the weight in lbs.

Ex. Required the weight of a uniform rectangular beam of cast iron, 16 feet in length, 11 inches in breadth, and $1\frac{1}{2}$ inch in thickness.

$$11 \times 1{\cdot}5 \times 16 \times 3{\cdot}2 = 844{\cdot}8 \text{ lbs.}$$

Resistance of Bodies to Flexure by vertical Pressure.

When a piece of timber is employed as a column or support, its tendency to yielding by compression is different according to the proportion between its length and area of its cross section; and supposing the form that of a cylinder whose length is less than seven or eight times its diameter, it is impossible to bend it by any force applied longitudinally, as it will be destroyed by splitting before that bending can take place; but when the length exceeds this, the column will bend under a certain load, and be ultimately destroyed by a similar kind of action to that which has place in the transverse strain.

Columns of cast iron and of other bodies are also similarly circumstanced, this law having been fully developed by the experiments of Mr. Hodgkinson on columns of different diameters, and of different lengths.

When the length of a cast-iron column with flat ends equals about thirty times its diameter, fracture will be produced wholly by bending of the material;—when of less length, fracture takes place partly by crushing and partly by bending: but, when the column is enlarged in the middle of its length from one and a half to twice its diameter at the ends, by being

cast hollow, the strength is greater by $\frac{1}{7}$th than in a solid column containing the same quantity of material.

To determine the dimensions of a support or column to bear without sensible curvature a given pressure in the direction of its axis.

Rule.—Multiply the pressure to be supported in lbs. by the square of the column's length in feet, and divide the product by twenty times the tabular value of E; and the quotient will be equal to the breadth multiplied by the cube of the least thickness, both being expressed in inches.

Note 1.—When the pillar or support is a square, its side will be the fourth root of the quotient.

2. If the pillar or column be a cylinder, multiply the tabular value of E by 12, and the fourth root of the quotient equal the diameter.

Ex. 1. What should be the least dimensions of an oak support, to bear a weight of 2240 lbs. without sensible flexure, its breadth being 3 inches, and its length 5 feet?

Tabular value of E = 105,

$$\text{and } \frac{2240 \times 5^2}{20 \times 105 \times 3} = \sqrt[3]{8 \cdot 888} = 2 \cdot 05 \text{ inches.}$$

Ex. 2. Required the side of a square piece of Riga fir, 9 feet in length, to bear a permanent weight of 6000 lbs.

Tabular value of E = 96,

$$\text{and } \frac{6000 \times 9^2}{20 \times 96} = \sqrt[4]{253} = 4 \text{ inches nearly.}$$

Dimensions of Cylindrical Columns of Cast Iron to sustain a given load or pressure with safety.

Diam. in inches.	Length or height in feet. 4	6	8	10	12	14	16	18	20	22	24
	Weight or load in cwts.										
2	72	60	49	40	32	26	22	18	15	13	11
2½	119	105	91	77	65	55	47	40	34	29	25
3	178	163	145	128	111	97	84	73	64	56	49
3½	247	232	214	191	172	156	135	119	106	94	83
4	326	310	288	266	242	220	198	178	160	144	130
4½	418	400	379	354	327	301	275	251	229	208	189
5	522	501	479	452	427	394	365	337	310	285	262
6	607	592	573	550	525	497	469	440	413	386	360
7	1032	1013	989	959	924	887	848	808	765	725	686
8	1333	1315	1289	1259	1224	1185	1142	1097	1052	1005	959
9	1716	1697	1672	1640	1603	1561	1515	1467	1416	1364	1311
10	2119	2100	2077	2045	2007	1964	1916	1865	1811	1755	1697
11	2570	2550	2520	2490	2450	2410	2358	2305	2248	2189	2127
12	3050	3040	3020	2970	2930	2900	2830	2780	2730	2670	2600

Practical Utility of the preceding Table.

Ex. Wanting to support the front of a building with cast-iron columns 18 ft. in length, 8 inches in diameter, and the metal 1 inch in thickness; what weight may

I confidently expect each column capable of supporting without tendency to deflection?

Opposite 8 inches diameter and under 18 feet = 1097
Also opposite 6 in. diameter and under 18 feet = 440
= 657 cwts.

Note.—The strength of cast iron as a column being 1·0000

"	steel	"	= 2·518
"	wrought iron	"	= 1·745
"	(oak) Dantzic	"	= ·1088
"	red deal	"	= ·0785

Elasticity of torsion, or resistance of bodies to twisting.

The angle of flexure by torsion is as the length and extensibility of the body directly, and inversely as the diameter; hence, the length of a bar or shaft being given, the power, and the leverage the power acts with, being known, and also the number of degrees of torsion that will not affect the action of the machine, to determine the diameter in cast iron with a given angle of flexure.

Rule.—Multiply the power in lbs. by the length of the shaft in feet, and by the leverage in feet; divide the product by fifty-five times the number of degrees in the angle of torsion; and the fourth root of the quotient equal the shaft's diameter in inches.

Ex. Required the diameters for a series of shafts 35 feet in length, and to transmit a power equal to 1245 lbs., acting at the circumference of a wheel $2\frac{1}{2}$ feet radius, so that the twist of the shafts on the application of the power may not exceed one degree.

$$\frac{1245 \times 35 \times 2\cdot5}{55 \times 1} = \sqrt[4]{1981} = 6\cdot67 \text{ inches in diameter.}$$

Relative strength of metals to resist torsion.

Cast iron . . .	= 1	Swedish bar iron .	= 1·05
Copper . . .	= ·48	English do. .	= 1·12
Yellow brass .	= ·511	Sheer steel . . .	= 1·96
Gun-metal . .	= ·55	Cast do. . . .	= 2·1

SMELTING.*

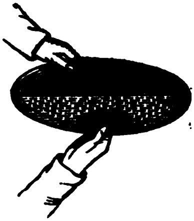
GOLD AND SILVER ORES, &C.

IN the assay by fusion the object is to produce a metal in its pure form, directly from the ore, and in some instances to produce all the metal of a certain kind which the ore may contain, with a view of comparing the result of the assay with the smelting process on the large scale. To succeed we must deoxidize the ore, and produce at the same time so much heat as to melt the metal; in addition, the foreign matter in the ore must be converted into a fusible scoria, which generally floats as a light glass on the top. Different ores require different modes of operation to produce the metal. Often a variety of the same ore must be subjected to different processes. For the latter reason we convert most ores, which are to be examined, into oxides by roasting. When a specimen is to be assayed we ought to know, at least approximately, its composition, in order to modify the manipulation accordingly. In most instances we recognize the quality by the appearance of the ore; in others, we apply the blow-pipe as an introductory examination. We shall, in order to facilitate the operation, describe the most prominent marks of the ores which may come under examina-

* Overman's 'Treatise on Metallurgy,' 8vo.

tion, and the class to which they belong. If an assay is ineffectual at first, it is repeated with proper modifications until a satisfactory result is obtained. There is not much difficulty in this, as it chiefly requires the production of a suitable slag.

Gold.—An assay of gold ore is not difficult. If we expect gold in a specimen, we pulverize it finely; then pass it through a fine sieve, and wash the powder in an iron pan, or a blackened pan of any kind of material. The annexed figure represents the manner in which the operation is performed. A pan is held in one hand firmly, and some water poured upon the ore; the other hand is now used for shaking the pan in a gentle but rapid manner. The powdered ore being thus gathered to one side, the heavy grains of gold



descend through the sand to the bottom of the pa and settle in the corner. After shaking the pan few minutes, it is to be moved so as to produce gentle current in casting off the water. This v carry with it some of the sand, and diminish quantity in the pan. In repeating this process v fresh water, another portion of sand is removed f the sample; and if the shaking and removal of is continued, the latter may be washed off ent or nearly so. The principle involved is, tha debris of rock is lighter than the gold; the will therefore sink to the bottom, and the f pass off, by moving the water gently on the s of the pulverized ore, which is always retained same place, in a corner of the pan. When tl is thus nearly washed away, a little water is

in the pan, moved around by inclining the pan, so that the water flows always into its corner or lowest part. This gentle current will move the debris of rock to another part of the pan and expose the metal to view. When this operation is performed on crushed rock, or on alluvial soil, it is in all cases necessary to pulverize the mineral that no particle of metal may escape detection. In this manner we cannot make a quantitative assay; for, with the greatest attention, we lose half of the metal. Gold is very fine when its ore has been crushed, and it is carried away by the water in washing off the rocky matter. In most cases we detect the gold in its metallic state. When an ore is thus treated, and we do not find it in the residue—which may happen in silver ores, in the tellurets, and sulphurets, and arseniurets—we crush the ore, as before, mix it with the fluxes, and smelt it.

Gold ores are not often so rich in metal that a small quantity smelted would furnish a safe estimate of the average contents of a mine. It is therefore necessary to assay at least 500 or 1000 grains at once, and repeat this operation on various parts of the vein. If the ore is a ferruginous slate, or quartz, it is intimately mixed with half its weight of pure litharge, half its weight of borax-glass, and one part of carbonate of potash: these ingredients must be well dried and the whole then finely pulverized. This mixture receives an addition of sufficient carbon to precipitate a certain quantity of lead in the metallic state; and as one part of charcoal produces 30 parts of metal, we add accordingly. From 1000 grains of ore, 100 grains of lead may be produced, which will contain all the gold present; and in order to obtain these, we add 4 grains of fine charcoal and

mix it intimately with the ore and flux. Here is more carbon than is required, but we must consider that a little carbon is always lost in the operation. This mixture is put into a Hessian crucible, which should not be more than half filled; for the mass, when heated, will boil and overflow the brim of the pot. Instead of carbon, black flux might be used; but as we do not know the amount of carbon in that flux exactly, we are exposed, in using it, to the producing of too much or too little lead. Over the test in the crucible a little common salt, a stratum of about a quarter or half of an inch thick, is laid, which will prevent the evaporation of carbon and accelerate the solution of metallic substances in the ore. The use of a graphite, or black-lead crucible, is inadmissible in this case; for its carbon would precipitate more lead than is needed, and cause it to be impure. The crucible and contents are now placed in the furnace, covered by a slab to prevent the falling in of coal, and surrounded with coal so as to cover the crucible; fire is then applied at the top by adding hot charcoal. The fire thus kindled will heat the crucible from the top downwards, which protects the pot and prevents its fracture. In half an hour the fire should be drawn to the grate-bars, and fresh coal added, sufficient for at least three-quarters of an hour; the furnace is then covered, the grate cleaned, and a vigorous heat applied. In half an hour the furnace-cover is partly removed, the cover of the crucible lifted, and the contents examined. If the mass is fluid but still boiling, that is, throwing up gas-bubbles, the pot is covered again; and when there is a deficiency of coal to last the heat out, a fresh supply is added to complete the assay. When coke or anthracite is used, we need not add fresh

fuel to a once charged furnace; the use of charcoal, however, makes this invariably necessary. As the addition of fresh fuel delays the operation, and is in some cases injurious to the assay, we see the importance of using hard coal, either coke or anthracite, in crucible smeltings. A strong heat, and one of short duration, is all-important in this assay; for lead is volatile, and the flux will at last eat through the crucible.

After the lapse of about ten minutes, the contents of the crucible are again examined; and if the mass is now found to be perfectly fluid and quiet on its surface, the covers of the furnace and pot are removed, the fuel rammed down by means of an iron rod, and the crucible withdrawn from the fire and set in a dry or warm place on the brick floor. The crucible may be withdrawn by a pair of blacksmith's tongs, the fire-lips of which are nearly as long as the shanks, thus causing very little pressure upon the sides of the pot. Basket tongs may also be used, similar to those of the brass-founders; but they are generally too heavy and clumsy for assaying operations. On putting the crucible down on the floor some few gentle taps are given to it, to gather in the bottom those globules of metal which are suspended in the slag. When the crucible is perfectly cool, it is broken over a basin with water, that its contents may be examined when wet. In the bottom of the pot, a button of lead is found; and on breaking the scoria, we may examine it for grains of metal. If no metal is visible with the aid of a lens, all the parts of the pot and the slags are thrown away; if metal is visible, the pot and slag is to be pulverized, and washed, so as to recover it. This operation is performed in a wash-pan, like that with the crude ore

above described. All the metal must be free
adhering slags by means of the hammer and
it is then weighed and a cupel selected of
weight, or heavier, for refining it.

Use of Salt.—In this assay we recommen
use of salt in the form above mentioned, an
mixed with the ore and other fluxes. Salt is
good flux, because it does not aid in the solu
silex directly; it merely dissolves the metallic
and prepares them to combine with silex. M
the metals combined with chlorine are very v
and in assays, other than those of the pr
metals, salt is inadmissible. Saltpetre is pref
to salt; but as the oxygen of the saltpetre i
absorbed by the carbon present in the mixtu
lead will be precipitated; or else all the saltpet
be converted into alkaline flux, which is not a
flux for gold or silver ores; it causes the lead
so impure as to cupel with difficulty. Some co
salt, or fluor-spar, is requisite to free the lea
iron, copper, and such metals, which delay and
spoil the cupelling of it. In these assays it m
the aim of the assayer to obtain pure lead in th
smelting; if it is not obtained, it must be re
with a little saltpetre, or a mixture of saltpet
common salt.

Sulphurets and Tellurets.—When gold or
not perfectly oxidized, which frequently happ
when pyrites are present, or the gold is con
with tellurium or galena,—the operation is som
difficult if we expect a correct quantitative
In this case, as well as in the foregoing, w
assay by means of litharge, using four or five
to one part of ore, or, in fact, any quantity m
less than that specified, and precipitate as muc

as we want by means of a specified quantity of coal or black flux. Such an assay is never correct; the slag is decidedly alkaline, and it retains a portion of the precious metal which may amount to 10, or 20, or even a greater per-centage of that contained in the specimen. In all cases when precious metals are to be assayed, and the object is to obtain the whole amount, the slag which is formed ought to be of an acid nature; if not acid, it should be, at least, a neutral salt. Gold is soluble in an alkaline slag, particularly in an alkaline sulphuret; and it cannot be expected to follow the metallic lead when so dissolved, or suspended in the slag. The means commonly employed for the purpose have proved insufficient, and the author has been induced to perform a series of experiments which resulted in a more perfect mode of assay, and in a smelting operation, the benefits of which he has secured to himself by a patent right. This operation is as follows. When the ore contains sufficient galena, no lead is added; but when it does not contain lead in some form or other, some finely-powdered litharge is added to the pulverized ore, and the whole intimately mixed. From ten to fifteen per cent. of oxide of lead is in all cases sufficient to procure all the gold. The pounded ore and litharge is mixed with about one half of its weight of common salt; the whole mass is moistened with water so as to dissolve the salt, and then exposed to evaporation under constant stirring. When dry, the contents are gently heated in an iron pot with a concave bottom, and as soon as any signs of melting are perceptible, the mass is diligently stirred by a bent iron rod. It soon becomes semi-fluid, and the heat should be modified so as not to make the slag perfectly fluid and evaporate the

chlorine, for the latter must be retained. Wh
slag has been well stirred for a short time,
small pieces of burning charcoal are adde
stirred with the cinder. The charcoal reduc
oxide of lead, and the heat must be so regulat
no lead can sink to the bottom of the pot,
suspended in the semi-fluid slag. By consta
ring, the particles of metallic lead absorb the
cles of gold which may be suspended or dissol
the semi-fluid sulphuret, and an alloy is ob
disseminated in small globules through the
About half an hour is sufficient time to fini
smelting operation; the iron pot is remove
the fire, and the mass quickly thrown int
water. Then the slag dissolves, the salt is ext
and there remains in the vessel a black, fine p
which feels like plumbago; it consists of tl
phurets of various metals, and metallic lead in
grains and spangles. The sulphurets are ext
fine, and are held in suspension in the strong
fresh water should be added at discretion, t
phurets gently washed away, and the remaini
gathered for cupellation.

By this mode of assaying all the gold is
obtained, but it requires a low heat and
work to make the operation successful. If su
iron pyrites is present, the addition of a litt
serves to secure the precious metal; if there
a little iron in the ore, a small quantity of o
iron should be added to decompose the sulp
A gentle heat, the presence of salt, and the s
cause the evaporation of some sulphur, also
and tellurium, and the sulphurets are thus d
of the power to dissolve gold. The gold
suspended in the pasty mass, and obtained b

bining it with metallic lead. If the combination is produced when the mass is in a state of rest, many particles of gold may be lost, because they are fine, and washed away with the water and the fine sulphurets; diligence is therefore necessary to make the operation succeed well. The presence of any alkali will injure this operation, and if some of the lead remains in the form of a sulphuret in the slags, the assay is doubtful. There is no danger of reducing the ores of iron, copper, or other metals by carbon; gold, silver, the platinum metals, and lead are the only ones which can be obtained. The addition of an excess of carbon under the influence of a limited heat has therefore no other effect than to increase the mass and the labour in washing. The lead obtained in this operation may be re-melted in a crucible along with a little saltpetre to form it into a button and to free it from impurities.

In ancient times, assayers melted pyrites in potash and soda, and dissolved the slag in warm water, supposing that all the gold was contained in the alkaline sulphuretted solution. But this was a mistake: gold is soluble only in alkalies which contain a large quantity of sulphur. Sulphur must, therefore, either be added to such an assay, or the gold will adhere to the metallic sulphurets and be precipitated with them. It is very doubtful if with the addition of sulphur the whole amount of gold is obtained in the solution, because it is not very soluble in that menstruum. Other metallurgists recommend to melt the pyrites with saltpetre and litharge, then to evaporate all the sulphur and produce metallic lead. This is a safe way of assaying, but as saltpetre is easily decomposed and forms an alkaline slag, it requires either a very large quantity of the flux, or the assay

is incorrect. It needs at least an amount of saltpetre equal to that of the ore when clean, and if the slag is not very liquid, a part of the gold will remain in it. The method of roasting or oxidizing the pyrites, and removing the oxide by washing, is so imperfect that it deserves no further notice.

If gold is contained in metals, such as refuse iron, tin, zinc, brass, or copper, under the form of works of art, it is scraped off with a scraper or file. This labour may be accelerated by oxidizing the metals at a low heat. The gold thus obtained, as well as jewellers' sweepings, are either melted with saltpetre, or with saltpetre and lead; in the latter case, some lead is obtained which contains all the gold, and may be cupelled in the usual manner. In this case tin or zinc is frequently present in the refuse, and as the oxides of these metals do not melt in saltpetre, it is advisable to add some common salt to the assay, to remove them from the lead, for these render the operation of cupelling slow and tedious; and if zinc or antimony is present, some of the gold is carried off by the evaporation of these metals. If sufficient saltpetre is used, and a little common salt, there will not be any other metals than lead and gold or silver in the button. It has been proposed to free gold from other metals by means of sulphuret of antimony; but this operation, which is generally practised by jewellers for refining their gold, is not applicable to an assay, because it is never correct. It has been also proposed to oxidize artificially all the metals which may be combined with gold, by using black manganese or oxide of iron. This method is not sufficiently correct to deserve any notice; for in all instances the oxides which are formed contain gold in small particles which never can be recovered.

The true principle of an assay for gold, in all cases, is to form a very fusible slag which absorbs all the metals; and as the gold will adhere readily to melted lead, it should be brought in contact with that metal in a state of fusion, and all the particles will be obtained. Common salt, or borax, remarkably promotes the solubility of metallic oxides, and in fact dissolves them very readily. In all cases, therefore, where we have to deal with metals or metallic oxides, either one or the other should be present; but, as borax causes other metals than lead to be formed, and salt produces only the precious metals and a limited quantity of lead, the presence of the latter is, in all cases, preferable to borax, when the precious metals are the object of the assay. There is no substance which dissolves metals more readily and converts them into oxides than chlorine, and when this is present in a sufficient quantity, the precious metals are not excepted; but when metallic lead is once produced in a crucible, it is only necessary to bring the dissolved gold in contact with the lead, and it is absorbed by it.

Metals and Gold.—When other metals are alloyed with gold, we separate the first either by cupellation, or if the kind and quantity is not suitable, we convert the first into oxide and divide the latter. The alloy of lead and gold is the most suitable for cupellation, and it is in all cases advisable to remove all other metals and convert the alloys into this combination. As gold is very volatile, these conversions must be performed by as low a degree of heat as possible. The cupellation of lead and gold is perfectly safe and easy: this is not the case with other metals and gold. Copper and gold combine very readily, and in fact more so than lead and gold, but

this alloy cannot be cupelled; it is therefore melted with lead, and the latter causes the oxide of copper to be absorbed by the cupel. The operation is uncertain, for the oxide of copper will absorb gold and carry it off. Such an assay is never correct, the refined gold containing copper, and the oxide of copper, gold. The same is the case with all other metals, and it is an object of peculiar importance not to cupel a test wherein other metals or substances than lead are contained. Other alloys than those of lead should be dissolved in muriatic acid, and precipitated by carbonate of soda, and the precipitate smelted like a mineral. In smelting, an excess of litharge is used; the quantity of lead is determined by the carbon which is added. An alloy of copper and gold requires a large quantity of lead for cupellation. We may assume that 100 parts of lead to one of copper is not too much, considering their relation, and the uncertainty of success in such an assay. It is easily understood that the solution of the alloy, and its precipitation with an alkali, is the only safe way of proceeding. As an alloy of gold always contains some silver, and as gold is not soluble in muriatic acid, the remaining parts which do not dissolve in the acid must be smelted with the precipitate. There would be no necessity of precipitating the solution, and merely smelting the residue would answer the purpose, but for the circumstance that chloride of silver is soluble to a certain extent in other or soluble chlorides; and as in most cases the amount of foreign metals is small, this method does not increase the labours of the assayer.

If the quantity of a metal in a test specimen is large, it is advisable to make a sulphuret of the alloy. This is accomplished in melting the speci-

men by adding gradually sulphuret of iron, coarsely pounded; the native pyrites contain sufficient to produce this effect on a large quantity of other metals. Galena may be used also, but it is not so effectual as iron pyrites. If neither iron nor lead pyrites can be obtained, pure sulphur is used, which is added to the melted or heated metal in small quantities and in the form of a coarse powder. The resulting sulphuret is then treated as native sulphurets, as has been stated in former pages.

Platinum, Silver, and Gold.—The presence of the first of these metals causes the cupellation to work slowly, and in some cases, particularly when copper is present, the gold does not form a globule at all, but is carried with the oxide of copper and the platinum metal over the cupel. In such cases we melt the test with some silver, of which at least twice the amount of the gold alloy must be added, and also some lead to make the mass fusible; it is then cupelled in a strong heat to obtain the metal in a perfect globule. The quantity of lead is variable; if the heat in the cupel is strong, which is the most advantageous, the quantity of lead may be 12 or 14 times that of the alloy. If the heat is low, but sufficient to melt the alloy, the quantity of lead must be at least 20 times that of the alloy. In all cases the resulting refined metal is adulterated by copper if that metal is present, which is more likely to be the case if the heat has been low in the cupellation. If no copper is present, less lead may be used in refining the metal. The presence of platinum in a test is recognized by the globule, which assumes a flattened instead of a round form,—this is pre-eminently marked in pure gold; silver, or an alloy with much silver, is also liable to form a flat globule in the shape of a hemisphere, while that of platinum is distinctly flat-

tened. One per cent. of platinum will cause the globule to be rough and rugged on the surface, while pure gold and silver is perfectly smooth and shows a mirror-like lustre. In all cases the presence of platinum causes the globule to be dull and lustreless, often showing crystals on the surface. When the alloy contains more than ten per cent. of platinum, the cupel is covered with a silver coating, under the influence of a strong heat, which is often yellowish or grayish, and consists of platinum metal.

Moist analysis.—When a globule of gold is obtained in the process of cupellation, it is never pure, particularly when derived from a mineral. The globule, for the purpose of testing it, is flattened on a steel anvil with a hammer; at first it is placed directly on the naked steel, and afterwards between strong and thin paper. It is next exposed to the influence of pure nitric acid, which must be free from muriatic acid, which will not cause a precipitate with nitrate of silver. If the gold is nearly pure it is not attacked by the acid; we melt it then with some pure lead, about equal to twice its weight, and dissolve this alloy. The nitric acid, gently heated, will now hold in solution the lead and silver, and leave gold, platinum, and the platinum metals at the bottom of the vessel. If pure silver is at hand it may be melted with the globule, of which an equal weight is sufficient. The result is more certain than by alloying it with lead. The residue of the solution is treated with aqua regia, which dissolves the metal. The solution thus obtained is evaporated in a flat porcelain dish, over a basin of boiling water, which causes the evaporation of all the acid. The dried chloride of gold is now dissolved in water, and to this is added a fresh solution of proto-sulphate of *iron*, which in a short time precipitates the gold in

the form of a yellowish brown powder. This is dull and lustreless, but assumes brightness when filtrated, dried, and burnished by a hard and polished substance. The proto-sulphate of iron is prepared by dissolving copperas, and adding to the solution pure metallic iron. This solution must be prepared some days previous to its use, for the iron does not dissolve very readily in the copperas. A surplus of metallic iron should always be in the solution. It is advisable to use both gold and iron solutions in a somewhat diluted state; it does not then form a precipitate at once, but requires some time. The mixed solution appears at first to be light blue, and in reflected light reddish yellow; the gold gradually subsides in the form of a yellow powder. This powder is pure gold; it is filtrated on clean paper, and may be weighed in this state, or it may be gathered into a globule with some borax and saltpetre in a crucible.

Remarks.—In all the assays of gold, we must be extremely cautious to avoid the presence of an alkaline slag; for in most cases some oxide or sulphuret of gold is always present in a mineral which contains gold. Both are soluble in alkalies, and if the slag we melt with is alkaline, we are uncertain of the results of the assay. Borax, potash, and soda are to be avoided, if possible; and the use of salt requires caution, for all these fluxes dissolve gold. Saltpetre is the most suitable flux, but in the presence of sulphur, carbon, and some of the metals, it is decomposed and ceases to be good. Chlorides are the most practicable fluxes; but as these cannot bear a high heat, nor one of long duration, the operation must be so arranged as to perform the assay in the shortest time which is possible. For these reasons

the fluxes and mineral are mixed in a wet condition, to bring the particles in close contact before heat is applied—this facilitates the smelting considerably. The moistened mass must be dried before it is packed into an earthen crucible, because it will break the crucible when it is deposited in a moist state. Gold is not often found in large quantities in minerals; and as a minute quantity is sufficient to pay for its extraction, the assay of gold ore claims an attention which is not required in assaying the ores of other metals. Chlorides dissolve the oxide of gold, but not metallic gold; and when fluid lead is brought in contact with the dissolved oxide or sulphuret, it will absorb them; but as lead is heavy, it is inclined to subside, and thus deprives the particles of gold, which still may be present in the slag, of an opportunity to combine with it: for these reasons we prefer the assay in an iron pot, with a constant stirring of the mass. The melted lead performs here the office of mercury in an amalgamation.

Platinum and Platinum Metals; Palladium, Rhodium, Iridium, Osmium. The latter metals are generally alloyed with platinum. Platinum is exceedingly refractory; it can be melted only when alloyed with another metal. When a grain of metal of a leaden appearance resists all degrees of heat, and neither melts nor oxidizes, we may conclude that it is platinum. If the grains of the metal are fine, and imbedded in rocky matter, it is treated as gold ore, melted with suitable fluxes, and cupelled. In this case silver must be present to cause the platinum to be fusible in the cupel. If no silver is in the ore, an addition of pure metal must be made to the assay. In a strong heat, platinum combined with two parts of silver may be cupelled. But as a strong heat is

not generally at the command of the assayer, it is advisable to make use of more than two parts of silver to one of platinum. In most cases it is the best plan to arrange the assay so that one part of platinum in the ore is melted with 6 parts of silver and 50 parts of lead. If less lead and silver is in the alloy, the metals palladium and rhodium do not remain in the globule, but are spread over the cupel. If the amount of platinum in the test is not more than five per cent., or $\frac{1}{20}$ of the silver, the appearance of the globule in the heat of the cupel is similar to that of pure silver. If $\frac{1}{10}$ of platinum is in the silver, the globule does not show the bright glistening surface of silver or gold, but is dull and gray. With $\frac{1}{4}$ of platinum it requires a strong heat, and the cupelling is extremely slow; the grain is flattened, dull, and obstinately retains the last portions of lead. The globule thus obtained in cupelling contains silver and platinum, and it may also contain gold and other metals; if thrown into concentrated boiling sulphuric acid, all the silver is dissolved, but not the platinum. The residue is platinum, and if gold has been in the alloy, it contains gold. It is then dissolved in aqua regia, some ammonia is added, and the solution evaporated over boiling water. The dry residue is triturated with alcohol of ·84 specific gravity, and dissolved in water after the alcohol has extracted the yellow liquid. The gold only is dissolved; the platinum remains as a platinum chloride combined with chloride of ammonia. This is calcined in a red heat over the spirit-lamp, and the remaining powder, which is platinum, weighed. The gold may be obtained by means of proto-sulphate of iron. Too much silver in the alloy is not good for solution, because some little platinum appears to be

soluble in sulphuric acid when the amount of silver is more than 2 to 1 of platinum; but as this loss is very small, the assay indicates too little metal. When iridium is present the precipitate of platinum-ammonium chloride is reddish or brick-red, instead of yellow. The precipitate is then calcined in a porcelain crucible and dissolved in aquafortis, which alone dissolves platinum; this, when precipitated by ammonia, forms a yellow precipitate. The separation of the other platinum metals from the solution, is, if not difficult, at least of such a nature as to belong more to chemistry than to metallurgy.

Silver.—The assay of silver ore is, in itself, extremely simple. Most of the silver ores contain lead, others copper, which metals in many instances so far predominate as to make their extraction profitable. We make the assay in this case with a view to procure the accompanying metal. In all cases it is necessary to combine the silver with some lead in smelting, and separate the silver by cupellation. If there is not sufficient lead in the ore, litharge must be added to increase it. The test can be melted with metallic lead, also, in case litharge cannot be obtained sufficiently pure. Metallic lead should be pure. It may be tried by cupelling a part of that which is designed to form the matrix for the silver. If it proves to be pure in the cupel—that is, shows no other colours, but converts that of the cupel into a uniform whitish-yellow and no metallic globule remains—we may conclude the metal to be sufficiently pure for the purpose. The assays with metallic lead, and those with the oxide of lead, have their peculiar advantages: the first is for quantitative assays in the smelt-works; the second is the most convenient for qualitative assays.

Assay by Metallic Lead.—We thus assay all the ores in which we expect to find silver or other precious metals. The lead used in this assay, the purity of which has been tested, is granulated in the following manner. The metal is melted in a clean iron ladle, the dross or sullage on its surface is removed, and the liquid poured into a wooden trough, which is previously rubbed over with reddle, in order to prevent the burning of the wood. The trough is

represented in the annexed figure. It is taken up with both hands, and the lead kept constantly in motion until it is near congelation; at this point the lead is thrown up, and in falling back into the trough again it is broken into small fragments, which are often very minute, and the mass appears in the form of fine sand if the operation has been well performed. When all the lead is thus divided, and cold, it is thrown on a sieve, of about twenty meshes to the inch; the fine part is removed for use, and the coarse grains which remain are reserved for remelting. This lead, in quantities of two ounces for one test, is placed upon a flat dish, and mixed with the ore for smelting. The dishes used for this purpose are manufactured of good fire-clay, similar to that of which crucibles or fire-bricks are made; a mixture of three parts of pure clay and four parts of refractory sand is considered a good composition.

Dishes of three inches diameter are made by hand of this siliceous clay, but where many are required, it is necessary to manufacture them by such a machine as is used for making cupels. The capacity of the dish must be abundantly sufficient to melt four ounces of lead and half an ounce of ore. These dishes, when first made, are too soft and porous for use: they are dried in the air and then baked in a furnace. Any potter can manufacture and bake them with his ordinary ware. With a cupel furnace, having a large muffle, a number of tests may be assayed at once; and in all cases, two tests should be assayed from every species of ore. Whenever meltings, smelting, and cupelling are done at the same time, the dishes, pots, or cupels, are marked with reddle, and numbered in such a manner that each test may be recognized: this reddle mark is not obliterated by fire. Two ounces of granulated lead are laid around the edge of the dish, so that the concavity in the centre is free. In the middle, $\frac{1}{8}$ of an ounce, or 60 grains, of ore finely pulverized, is placed, and some of the granulated lead mixed with it, in such a manner that the ore does not reach to the edge of the dish. The dishes thus prepared with ore and lead are pushed slowly into the heated muffle of the furnace; the most refractory specimens foremost, and those afterwards which melt easily. The ores which contain much siliceous matter or iron are refractory; those which contain pyrites chiefly, are very fusible. In a short time, say five or eight minutes after exposure to the heat of the muffle, the ore begins to roast, that is, exhale sulphur, arsenic, and other volatile substances, and the lead begins to melt. When ore and metal are thus heating, the mouth of the muffle is shut by a piece of hard charcoal, and the dishes

gradually exposed to a stronger heat by stirring the fire: this must not be done too fast, because some ores foam in melting and flow over the lead, thus spoiling the assay. The principal object of this operation is to form a slag of the ore, and bring at the same time melted lead in contact with it in its molten state, which may absorb the precious metal. In case the ore does not contain sufficient flux for melting, some of the lead is oxidized by the heat, and forms a flux for it. It is therefore evident that too much heat is disadvantageous to the ore, because some of it may boil over the edge of the vessel and is lost. The heat must not be too slow to act, because in that case the oxide of lead, which is generated abundantly, will eat through the dish. The heat in the muffle is easily regulated by putting more or less coal at the mouth. It is therefore advisable to have the fire rather too strong than too weak. After the lapse of fifteen or twenty minutes we observe a bright metallic spot in the middle of the dish. It is the melted lead surrounded by the fluid ore, which is now in the form of a slag. The lead is all the time burning and evaporating; and if these vapours of it draw over the dishes, it is an indication that the heat is too low; on the other hand, if these vapours rise high on the roof of the muffle, the fire is too hot. The vapours of lead ought to form a cloud, which is suspended half-way between the roof and the bottom of the muffle. The withdrawal of coal at the mouth of the muffle will cool it, and the addition of coal heat it. When the bright spot in the middle of the dish disappears, the mouth of the muffle should be entirely shut, and a strong heat applied about ten minutes longer. This is the finishing heat; the ore becomes now perfectly fluid,

and separates entirely from the button of lead below it. This heat is sufficient to finish the operation. The time consumed in the assay is between one hour and one and a quarter. The dish is now withdrawn from the hot muffle, and its contents cast into a previously heated iron mould which has been rubbed over with some fat or tallow. After the contents of the mould are cooled sufficiently to adhere together, they are put into cold water, and the slag carefully separated from the lead by striking it with a hammer. This lead is ready for refining, and may be placed in the cupel. In case the ores contain very refractory matter, such as particles of clay, slate, heavy spar and quartz, about ten grains of borax-glass may be mixed with the ore; but if the test will work without, it is better. If a series of tests are to be assayed, it is the best plan to melt the whole of them before refining the lead.

Smelting with Oxide of Lead.—All ores may be smelted with the oxide of lead instead of metallic lead, which is preferable when much lead is in the ore. Some ores must be roasted before melting; these do not often present themselves, and generally we may smelt without previous roasting. The ore under examination is finely pounded, and mixed with double its weight of a mixture consisting of one part of saltpetre and two parts of crude cream of tartar. This is the composition of black flux, which may be used here to advantage in its crude form, particularly when sulphur is in the ore. The use of this mixture presupposes the presence of lead in the ore and one ounce is smelted at a time; this brings the quantity of ore assayed to near five hundred grains. If no lead is in the ore, or very little, an equal weight of pure litharge is mixed with it, and the other pr

portions are the same as mentioned before. In most cases it is the best plan to take 100 grains of this kind of ore, and mix with the required flux for smelting. If we want a correct assay of lead, the test is not smelted in an earthen or clay crucible, but in a copper pot, so that all siliceous matter is excluded. In the figure annexed, a pot of this kind is represented. It is about $\frac{1}{4}$ of an inch thick in metal, and as the flux is exceedingly alkaline, very little lead can remain in an oxidized state in the slag. Over the mixture of ore and flux a stratum of salt is laid. This is necessary to prevent the flying of the ore. The crude flux, in detonating with the saltpetre, would throw out the ore unless it was covered with salt, especially if the narrow mouth of the copper pot was open. A short time, 35 or 40 minutes, is sufficient to smelt the test, for which of course the heat must not be made so high as to melt the copper. This test may be smelted in an iron pot if the ore contains no sulphur. When the smelting is finished, the contents are poured into the iron mould, and the quantity of lead which is obtained shows the exact quantity of that metal in the ore.

When oxide of lead is added to the assay, no test can be made for determining the quantity of lead. The operation is essentially the same as that above mentioned, and may be performed in a clay or Hes-

sian crucible, in a black lead pot, or an iron pot. The lead thus obtained is cupelled. In all cases where crude tartar is used as a flux, the fire must be kindled above the pots, for if it comes from below, the detonating saltpetre is apt to throw most of the ore out, in spite of all precautions. The fire must be low so long as a noise is perceived in the pot; when that ceases, the draught-holes may be opened and more fire applied.

In this assay we may use litharge, as in the gold assay; that is, take an excess of litharge and precipitate lead by mixing with it a definite quantity of carbon. But in this case, as in the previous one, a large quantity of silver may remain in the slags. This is of less importance than in the case of the gold assay; still it is sufficient to cause an assay made in a clay crucible to be incorrect. In all these instances we recommend smelting in an iron pot, with salt and a constant stirring of the mass, and the extraction of the granules of lead by dissolving the cinder. This assay furnishes a more correct result than any other.

When sulphurets are extensively present in an ore, the operation is in all cases performed with greater facility if the test is smelted with saltpetre only, or a mixture of saltpetre and litharge, to which carbonate of soda is added. Galena may thus be conveniently assayed for silver, if we pound it with three or four times its weight of saltpetre, and dry carbonate of soda of a weight equal to its own, or the same quantity of oxide of lead. Thus a small quantity of lead is produced which contains all the silver, but not all the gold if any is present. The sulphurets may be also smelted in a clay pot, with just sufficient saltpetre to oxidize all the sulphur and

produce no metallic lead. The slag thus formed is covered by a sheet of metallic lead, which in melting down carries all the silver with it. This operation may be correct when executed properly, but it is one of those difficult assays in which the result depends on the skill of the operator. When an assay is performed in an iron pot under constant stirring, all the sulphurets of an ore may be decomposed by litharge; when to this, metallic lead is added and the assay in its fluid state is poured into a hot clay crucible and rapidly melted, so as to accumulate all the metal at the bottom, we may obtain all the silver in the ore, but not all the gold. If a mixture of ore and flux of litharge is so regulated as to form an oxide, the ore never boils on melting; we may therefore in such a case fill the crucible, and cover the top of the ore with pure litharge. As much metallic lead will be produced as is indicated by the amount of sulphur in the ore, which in iron and copper pyrites is considerable. An assay of this kind must be made in the shortest possible time, for the litharge soon eats through a Hessian crucible. Thus we obtain all the silver, and the process is simple and easily performed; the heat necessary is too great for an iron or copper pot, and if the assay is well regulated, the amount of metal produced may by proper attention be considerably diminished.

The first method, that is, the assay with metallic lead in the muffle of the cupel furnace, is the most correct, and whenever any doubt exists, it may be resorted to as a final proof of a good assay. It can be applied in all cases where the presence of the precious metals is expected; it is a quick operation, causing but little labour to perform it on an extensive scale. It is the best method of assaying. The

use of borax facilitates the operation in some measure, but when more than $\frac{1}{16}$ or $\frac{3}{32}$ of the ore is employed, the assay works slower and is not quite correct.

When metallic ores are exposed to heat and such re-agents as develope the metal, it is commonly called smelting, in contradistinction from the mere application of heat, which causes ore to become fluid, and is called melting. Smelting is a chemical operation, conducted on the same principles as a moist assay in the laboratory; excepting that we produce in this case but one valuable substance, the metal, and consider the slags as accidental results. The slags require the closest attention of the metallurgist, because if they are of the right composition, the metal will invariably appear in the proper form. In all cases of smelting, it is an essential condition that the degree of heat should be so high as to cause all substances to become perfectly fluid. In principle there is no difference—if we mix two fluids, or a fluid and a solid, which show different affinities for the matter in solution—if the fluidity is produced by matter which is fluid at common temperatures, or only at a high heat. If oxide of iron is put into a watery solution of the sulphuret of potassium, the result is sulphuret of iron and potash; if the sulphuret of potassium is melted by heat, and we put into the fluid the oxide of iron, we have the same result; sulphuret of iron and potash are in the hot, melted mass. If some potash or soda is put into a red-hot solution of silicate of lead, metallic lead is precipitated, because the potash has more affinity for silex than oxide of lead. When into a fluid silicate of iron, carbon, lime, or other bases, or an oxide of metal is brought, such as manganese, which has more

affinity for silex than iron—it will deprive the silex of its iron, and precipitate the latter in its metallic state. The manipulation in the laboratory differs from the manner of operation in metallurgy, but we recognize in both the same laws of affinity.

In almost all smelting operations the object is to produce a certain metal, and to form of all the other metals oxides and slags. This operation is greatly facilitated by the fact that most of the metals are specifically heavier than their melted oxides, or than these oxides in combination with silex or other acids; and if slags and metal are actually rendered perfectly fluid, they will separate in consequence of their want of affinity and their difference in specific gravity. This case is like that of common fluids. Water and oil may be mixed, but they soon separate, the oil floating in a distinct stratum on the surface of the water. Metallic lead and oxide of lead, or a silicate of the oxide of lead, or any other silicate, may be mixed when in a rigid state, and they do not separate; but when both are fluid or melted, metal and slag soon separate, the former being found below the latter. When lead, iron, and slag are melted together, we obtain lead for the lowest stratum, iron on that, and the slag above the iron. The specific gravity of each indicates their relative positions. In all smelting operations we obtain at least two separate strata, often three, and in some instances four, of different substances.

Metals.—These are contained in the ores, in most cases, as compounds; and if it is the object to separate them, we are to put such matter in contact with them as will deprive the metal of its compound. If a silicate of iron is melted, we do not precipitate iron by adding carbonate of soda or caustic lime to the

fluid mass: this addition merely increases the fluidity of the slag without producing any metal. But if we add sodium, the oxide of iron will be deprived of its oxygen and form metal. Carbon has more affinity for oxygen than metal in the high heat of a melted silicate; if therefore we add carbon to the melted silicate of iron, some iron is produced in all cases. When in this instance sufficient iron is precipitated to deprive the slag of its fluidity, no metal is formed, however much carbon we may add; for the metal requires a slimy, glassy coating to protect it against the influence of oxygen. When exposed in small particles to the influence of oxygen, almost all metals burn more readily than carbon,—gold, the platinum metals, and silver, in some measure excepted. If therefore we desire to obtain metal, we must produce a slag which protects it and at the same time admits of its coagulation. If to fluid silicate of iron, potash or soda is added, and at the same time carbon, metallic iron will be produced, because the slag retains its fusibility by this addition; but when so much iron is precipitated as to render the slag not sufficiently fusible to cover the metal with a slimy coating, the presence of potash even will not prevent the iron from burning. Carbon in any form has a strong affinity for oxygen, and precipitates all the metals from oxidized compounds; but it must never be forgotten that metal in fine particles has more affinity for oxygen than carbon, no matter how high or low the temperature may be. It is evident from this that no metallurgical operation can be perfect until the heat is sufficient to melt both metal and slag. Some metals are extremely refractory, and do not melt in any heat we can produce by means of carbon; such are platinum, chromium, iron, and

others. In these cases we combine the metal with other substances which cause it to be fusible. Platinum is fusible in combination with lead; chromium in combination with arsenic; and iron in connection with carbon, phosphorus, arsenic, sulphur, and a number of alloys, is fusible, while by itself it cannot be melted. By these means we may precipitate and melt a metal which without such an addition would not melt. Silver and gold, if pure, do not melt very readily, and they evaporate at a heat only little higher than their melting point; it is therefore necessary to combine these metals with one that is more fluid, in order not to lose much of them. These considerations will lead the metallurgist to employ the proper means for obtaining the metal in a fluid state.

Slags.—As was remarked above, the composition of the slags determines the quality and quantity of the metal produced; and if considerations of economy did not interfere with the application of fluxes, other than natural ones, there would be no limit to the production of metals in quality and quantity. Slags are glasses compounded of substances which melt at a particular degree of heat for each definite composition. The study of the nature of slags forms the science of smelting; the metals follow of course when the fluxes are correctly compounded. It is not always the case that metals are obtained at first melting; some ores are first converted into matt, such as copper, then roasted, and the metal extracted by a series of roastings and smeltings. These operations, all made with a view of compounding a proper slag, complicate the smelting process so far that we distinguish in them oxidizing, melting, reducing or smelting, and refining. Each

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of these operations involves different principles
we shall for these reasons speak of them l
treating of the composition of slags.

Oxidation.—When sulphurets which cannot
be desulphuretted by roasting, such as copper py
are to be smelted, we either melt and roast by
spheric air, or by the addition of oxides t
melted mass. When iron pyrites is melted tog
with the oxide of iron, a large portion of sulpl
evaporated in the form of sulphurous acid, an
remaining sulphuret of iron when exposed t
atmosphere is easily decomposed; part of it is
verted into green vitriol, and the rest forms pe
of iron.

The oxidizing operation is facilitated either w
without the assistance of atmospheric air, by a
highest oxides of metals, such as oxide of lead
oxide of iron, black manganese, saltpetre, co
salt, silex, water, and in fact any substance
gives off oxygen, or facilitates an absorption of
spheric oxygen. Oxidizing smeltings are ofte
cheaper than roasting, and this is an object
well deserves the attention of metallurgists,
especially as it requires less labour and fuel to o
sulphurets in this manner, than by roasting, p
ing, and washing. In the large operation we c
employ litharge or saltpetre as a means of oxid
because they are too expensive; but instead of
we use coarse silex, gypsum, salt, oxide of ir
black manganese. In this case it is all-suffici
mix the mineral with such substances as cause
divide and offer more surface to the atmospheri
The substances used for oxidation are depe
entirely on the quality of ore, and the mo
operation in the subsequent reducing process

roast galena with fine silex, which of course will n liberate the lead from sulphur, not much metal be obtained, because the slag formed by the le of lead and silex is so far infusible as to admit no separation of the lead from it. But if the x is used in large grains, which leaves sufficient ces for the globule of melted metal, we may ob- ı as much metal in the presence of an excess of eous matter as in a perfectly fluid and alkaline ;. This of course excludes the possibility of a .ble slag, but it serves as an illustration of the ıciples involved in smelting. Any other sub- ıce than silex may serve the same purpose, pro- ɔd it has no affinity for that which is to be ıoved by evaporation, and is sufficiently refrac- r to resist melting with the oxide produced by ; metal which is to be oxidized. The most ex- ıive application of oxidizing melting is made in lting sulphurets of copper in reverberatory fur- es. In this case iron must be always present; this al combines with sulphur more readily than per, but it also parts with it more readily, when osed to the effect of the oxygen of the atmo- ere: the oxides of iron thus formed absorb sul- r from copper as long as any is present; and n all the sulphur is expended the iron forces the per from its combinations with silex. Common is profitably employed for oxidation; all chlor- are volatile, and so is common salt; but if the ntity used is small, and it serves as a mere stant in the operation, it will long resist the in- nce of heat, particularly in alkaline slags. In presence of clay or lime, common salt will bear gh heat for many hours without scarcely evapo- ıg. Salt to the amount of one or two per cent.

in the slag will resist the heat of a puddling-furnace for 24 hours, without being expelled. Sulphates act like chlorides, but it is necessary that no carbon should be present; the latter will decompose any sulphate in a melted condition, and it ceases then to act as an oxidizing agent. The presence of carbon facilitates the evaporation of chlorides also, but that which remains is still a powerful means of oxidation.

The oxidizing operation by smelting is always imperfect, that is, all the volatile substances, such as sulphur, arsenic, antimony, and phosphorus, are never removed entirely, and the metal is obtained gradually. The presence of the volatile matter serves in part to liquefy the slags. By these means, copper, lead, antimony and a few other metals may be obtained; but when it is an object to produce all the gold and silver contained in an ore, every particle of sulphur, &c. should be removed, and the mineral brought to the highest state of oxidation, before subjecting it to the reducing operation with carbon.

Reducing.—The means employed for obtaining metals from oxides, and other compounds, are so extensive and varied, and the apparatus so well adapted for accomplishing the object in view, that speculations on this subject are the most interesting of all branches of industry to which intellect may be applied. Conducted on the principles developed by chemistry, the mineral may require water for solution or heat; but as the composition of minerals is extremely variable, the means employed are of course equally so. The heat ranges from the boiling point of water to the highest attainable. The means of reduction are, metals, and to some extent

the oxides of the heavy metals, alkalies and alkaline earths, carbon, hydrogen, carburetted hydrogen, and a variety of other matter.

By Metals.—If we put into a fluid solution of sulphurets, arseniurets, or oxides, a metal which has more affinity for sulphur, oxygen, arsenic, &c., than one of the metals in solution, the latter is precipitated, and the first assumes its position in the fluid mass, provided it is soluble. If it is not soluble it will still absorb the substance for which it has most affinity from the metal, and float upon the reduced metal, provided the latter is heavier and both have little affinity for each other. This operation must be conducted with all the niceties of a chemical experiment. When sulphuret of lead or antimony is melted, and pure metallic iron is placed in contact with it, the iron will absorb the sulphur from these metals and produce them in their pure condition. Lead has little or no affinity for iron, the metal produced is therefore pure. Antimony combines readily with iron, and if the quantity of the latter is larger than merely to absorb the sulphur, it will combine with iron and form an alloy. In the first case it does no harm if more iron is used than is required, but in the latter it is injurious to the metal which is to be reduced. The quantity of the substance used for liberating metal from its combinations is here of equal importance as in chemistry, and the same laws are applied; the quantity increases the affinity. When a large quantity of iron is present in copper ores, we may succeed in obtaining almost all the copper; but when little iron is in the slag, the copper has such affinity for either volatile matter or silex, that a large per-centage remains in the slags, which can be recovered only by heavy expense. In

all operations of this kind we are therefore to consider the affinities and also the amount of the mass.

By Oxides.—When a mixture of potash and soda is melted, and we add to it a sulphuret of a metal whose basis melts below the heat of the alkaline sulphuret, and whose sulphuret is not soluble in the alkali, we obtain a certain portion of the metal, and often the whole of it. Zinc blende, galena, and the sulphurets of the fusible metals, form pure metals which separate; but iron or copper pyrites form no metal, because they do not melt in that heat, and remain either as oxides or sulphurets in the solution. Sulphurets of gold, platinum, or silver, do not produce metals, but when lead is present a part of these metals may be obtained. The sulphurets of arsenic and tin do not form metals, because these combinations as well as their oxides are soluble in alkalies. The same law which is here applied to potash and soda is applicable to the alkaline earths, and metallic oxides when these form fluid slags. Lime will effectually reduce the sulphuret of any metal, but as the heat by which it melts is very high, we can produce only those metals which do not evaporate at that heat. If the vapours of the metal are equally valuable with the melted metal, such as quicksilver and zinc, we reduce sulphurets by the use of lime successfully. When lime is used to excess in reducing sulphuret of iron, the latter may be freed from sulphur almost entirely. In the same manner, protoxide or magnetic oxide of iron acts upon galena; if the iron predominates and becomes fluid at so low a heat as not to evaporate the lead, all the lead may be obtained. The application of these principles is extremely important in metallurgy, and it deserves more attention than is commonly paid to it. Oxides

of metals cannot be reduced by other oxides, unless the higher oxidization of a newly formed oxide is more soluble than the previous one. When oxide of lead or of tin is cast into an alkaline silicate of iron, some metal is produced; this is not because the higher oxidization of iron causes the slag to be more fluid, but because some of the iron may be more highly oxidized without interfering with the fluidity of the cinder; the addition of some oxide of lead which remains, causes it to be more fluid, or at least retain its fluidity.

Carbon.—Of all the means at the disposal of the metallurgist, carbon is the most available for reduction. It is of little use in reducing chlorides, sulphurets, and arseniurets—for these metals are necessary: but as most minerals are in the form of oxides, and carbon is, in the high heat required, a strong agent in removing oxygen, it is generally applied. Hydrogen is also an effective means of reduction; but as its compound, water, oxidizes hot metal readily, and as the heat by which it operates is generally too low to melt the metal, its application is extremely limited. Hydrogen is employed in some cases, in its combinations with carbon, to reduce oxides, such as oxide of tin, or zinc; but it is then used to a very limited extent, such as the small quantity which is present in the coal employed, whether bituminous mineral coal or soft charcoal. This gas has in many cases a decided influence on the smelting operation, as we shall see; and it is mostly removed by charring that fuel which contains hydrogen to an injurious extent. Carbon is particularly suitable for the reduction of oxides in consequence of its volatile compounds with oxygen, and its harmless combinations with the metal produced.

The results of the deoxidizing operation, that is, carbonic acid and carbonic oxide, are extremely volatile, and escape without any injury to the slags, or the metal produced. When carbon is brought in contact with oxidized ore, and there is no other oxygen present but that in the ore, it will be forced to combine with that. When a mixture of carbon and ore is exposed to fire, no combination between the ore and carbon can ensue, because both are rigid and the particles cannot move; and as motion is indispensable in any chemical operation, no combination between carbon and the oxygen of the ore could happen, unless one or the other was made fluid by heat. In the first place, there is always some air, particularly oxygen, in the pores of charred coal—also in the pores of ore; this oxygen is at liberty to move and will combine with carbon, and as carbon is sufficiently abundant the combination formed is carbonic oxide. This gas will combine with another portion of oxygen where it finds such at a sufficiently high heat; and inasmuch as the ore nearest to it is hot, the gas will absorb oxygen from the ore and escape in the form of carbonic acid. The ore thus deprived of oxygen produces metal. This explanation may serve in all those cases where the metals readily part with their oxygen, but it is not sufficient to explain the reduction of metals which have a strong affinity for oxygen and even melt with their oxides. For these reasons the refractory metals are smelted with fluxes, which cause the ores to become fluid, and in this manner they are brought in close contact with the coal. The use of fluxes is, therefore, not confined to the absorption of foreign matter: it is highly valuable in accelerating the smelting operation. For this reason we see the

oxides of lead, bismuth, antimony, nickel, and cobalt, reduced very readily; because the oxides themselves, or mixed with fluxes, form fusible slags which readily flow over the carbon and cause a close contact between it and the oxygen. Tin, zinc, iron, chromium, and manganese, are not easily reduced, because their oxides are very refractory, and the first two metals evaporate in that heat at which carbonic acid is formed from their oxides: for these reasons it is necessary that soft charcoal or bituminous coal be used in their reduction. Neither the oxides of the other metals, nor the metals themselves, melt readily; but if we cause the oxides to become more fusible by adding fluxes, and the metals by alloying them with a substance which makes them fusible, we may produce either of these metals very readily. The reduction in most cases takes place previous to melting—and it is in fact not necessary that the ore should be melted before reduction ensues; but if it should be, it facilitates the formation of metal.

The doctrine that carbonic oxide is the agent in the process of reduction is not objectionable, so far as those metals are concerned which are not oxidized by carbonic acid, and which do not absorb carbon. This theory does not, therefore, apply generally. Some metals decompose carbonic acid—they cannot be reduced by it or in its presence; others again absorb carbon, which neither carbonic acid nor the carbonic oxide can afford; and it is necessary to adopt a hypothetical compound of carbon and oxygen in order to explain the carbonized state of some metals, such as iron, lead, manganese, and others. The combination of carbon and metals appears to be in most cases a mere mechanical mixture, and it can-

not be assumed that the affinity of metals for carbon is so strong as to decompose carbonic oxide. We shall illustrate this subject by referring to a particular case in which carbon is of peculiar effect, namely, that of iron. When iron ore is smelted in a blast-furnace, it is found not only difficult, but almost impossible to manufacture gray iron from magnetic ore, when not roasted or oxidized previous to smelting. It is impossible to make gray iron by smelting silicates of any kind, such as forge cinders or puddling-furnace slag. If only the presence of carbonic oxide was required, these forms of iron ore ought to furnish gray iron as well as any other ore, for the ore is constantly in contact with that gas and with pure carbon also. We explain this by referring to the compact form of the ore. All the ores which are compact are reduced by the carbon acting on the exterior particles of the lumps. The metal formed being fluid, runs off by accumulating into a body, which is in that form not accessible to carbon, or capable of forming any compound with other matter, because the points of attraction and contact are wanting. No matter, however, what the rationale of this phenomenon may be, the fact is generally known. Porous iron ores—spongy hydrates—are the most suitable to produce gray iron; in fact, they produce it as a necessary consequence of their form. If the latter was not the cause, this ore would be as little suited to form gray iron as any other, for it is of the same composition as specular ore, containing generally, however, more impurities than the latter; still it is very difficult to make gray iron of specular ore, and in fact of every kind of compact ore, no matter what may be its composition. Compact ore may be either perfectly pure or very impure; neither

condition renders it suitable to form gray iron. If iron, or its compounds, are in a porous condition, there is not the slightest difficulty in combining them with carbon. We conclude therefore that carbon penetrates into the pores of ore and metal in a solid form; for it is evident that spaces are required to bring particles of carbon in contact with particles of ore, or the compact ores would form gray iron quite as well as porous ones.

If porosity of the ore or metal is an essential condition of carbonizing it, then it is evident that carbonic oxide gas cannot have the power of conveying solid carbon to the metal, for that gas will penetrate less porous bodies than iron ores of a compact form. When carbonic oxide gas is the agent, it will carbonize iron wherever it finds it in a proper condition; for if it is fluid, all the requisites of combination are presented. Still, we know by experience that pure carbonic oxide will not carbonize iron in the converting box of the steel manufacturer; it requires the immediate contact of solid carbon and solid iron to form a carburet. Iron may be carbonized and decarbonized when in a fluid state, but the operation is extremely slow, and cannot be supposed to happen in a blast-furnace where the melted metal sinks down into the hearth rapidly. We assume, therefore, which assumption is supported by experiment, that carbon in a solid form is deposited in the pores of the ore before it is melted, and that in melting, the cohesion of the metal brings the carbon into so close contact with the metal as to force it into its pores and effect a union. The carbonizing of iron in the converting box presents no objection to this theory, as we shall see hereafter.

When carbon is present in the ore before it is

melted, how does it get there? how is it deposited in that form? Carbonic oxide cannot deposit carbon, for it finds abundance of oxygen in the ore to combine with, and will naturally form carbonic acid. But supposing carbonic oxide was decomposed in the pores of the ore, the result must be carbonic acid in all cases, which is evidently not the fact in the blast-furnace, for we find the latter filled with carbonic oxide nearly to its top; at least so far down as any carbonic acid is formed, no perceptible alteration is observed in the ore. From the lowest point where carbonic acid ceases, downwards, the effect of carbon commences, the cementation of ore goes on, and still there is little or no carbonic acid gas in the furnace. A cold plate is blackened when held over the flame of a clear-burning candle; solid carbon is deposited from the gaseous solution of the flame. It may be objected to this parallel example, that in the flame of oil and of fat there is an abundance of hydrogen, which holds carbon in solution. May not carbonic oxide have a similar effect on carbon as hydrogen when at a high heat? The solvent power of this gas for carbon may be very faint, existing only at a high heat, and being destroyed at a diminution of that heat. The operations of the blast-furnace, the mode in which the blast is introduced, and the appearance of the ore and gas in the furnace, confirm this theory of carbonizing iron.

Alloys.—If we adopt the foregoing theory for combining carbon with metals, we obtain at once a clear, comprehensive view of the conditions under which alloys, and the various combinations of metals and other substances, may be formed; and as these combinations are of the utmost importance to the metallurgist, they are well worth the trouble of a

examination. It is not only the combination, lso the separation of such combinations, which f interest. The above demonstration shows at under what conditions alloys may be formed, if the affinities and other relations are averse ıy combination. We may melt pure iron and ic metal together as long as we please, no union e two can be effected; the arsenic evaporates e the iron is sufficiently hot for its combination. f we heat fine iron filings and arsenious acid carbon, at first gently, we may melt both toge- very readily and obtain an extremely fusible iuret of iron. This operation is still more ' performed if we heat borings of gray cast iron ırsenious acid together. And this alloy may be ıced in any form or compound which we choose, mix arsenious acid, oxide of iron, and carbon in s together, and bring the various particles in contact before heating, by moistening the mix- with a weak solution of potash or soda, and g the whole before smelting. A very slight will melt this alloy, and all the iron in the mix- is readily obtained under a cover of carbon. most refractory metals may thus be made le, and obtained from their ores, and the facility which they are produced depends on the gement which we have made before smelting is ıenced. Chromium is very refractory, but if ıix its oxide with carbon and a little phosphoric and moisten the mixture with an alkaline solu- so as to bring all the ingredients into close ct before smelting, we obtain chromium at a ıeat in a perfect button, which is of course erated by phosphorus. It is extremely tedious luce potash so as to obtain potassium in a pure

be effected. If we had it in our power t
perfectly pure oxide of iron, and mix it wi
fectly pure carbon, and exclude any other
such as silex, from coming in contact wi
mixture, steel might thus be formed to per
But as one of the first conditions in thus pr
steel is the absence of all other matter excep
carbon and pure oxide of iron, we may rea
doubt the possibility of producing good s
these means, because on a large scale neithe
of iron nor carbon can be obtained sufficientl
It is therefore necessary to produce metallic
that form in which it has the least impurities,
is, pure wrought iron,—and cement it in
manner that other substances than those wh
volatile cannot come in contact so as to penet
mass. When iron melts by excess of heat
converting box, it is changed into impure ca
of which steel cannot be made; in this flui
it absorbs so much silex from the charcoal
forms a brittle compound.

When melted galena is passed over red-hot pure iron, metallic lead and sulphuret of iron is produced; and when fluid carburet of iron (gray cast iron) is poured into fluid litharge, iron and metallic lead are produced. When an alloy of lead and tin is mixed with melted iron, the latter will combine with the tin and separate the lead. Gray cast iron, mixed with a silicate of iron, will reduce so much of the oxide of iron as its carbon indicates; this operation is often accidentally performed in the puddling-furnace of the iron-works.

From these speculations it is easy to infer the great importance of the composition of the slags for the purity of the metals produced. In all smelting operations, slags must be formed in order to remove the impurities of the ore; and when carbon or any other substance is combined with the metal produced, and that may be retained in the cinder when the metal passes through it, in most cases the carbon, &c. will change places with some substance in the slag. The metal is thus adulterated with the substance taken from the slag. This subject is of extreme importance.

Separation by Weight.—In reducing metals from their ores, it must be the aim of the operator to form globules, and at the same time form such spaces through which they may descend. In a mixture of ore and carbon, if the latter is so fine as to prevent the descent of the metal, this may be perfectly reduced, and still no accumulation ensues: this happens particularly when an excess of carbon is used, and as this is inevitable in large operations, it is advantageous to select the coals in coarse parts. The larger these globules, the size of which is facilitated by coarse carbon, the faster their descent will

be. When small globules reach a mass of fluid slag, and are too small to penetrate it, they will remain on its surface, and even may be suspended within the body of it. This phenomenon happens frequently at blast-furnaces;—it may be, at those for smelting lead, copper or iron; a stiff slag will always retain metal in round grains, which is often found to amount to a considerable portion of all which is produced. If the slags are thrown away, this metal is entirely lost; but it may be recovered by pounding and washing the slags. At iron furnaces this loss amounts on an average to five per cent., often more: it is considerable at copper and lead furnaces, and in fact cannot be avoided in any smelting operation. The larger the globules of metal, the less are they liable to be retained by the slag. It is therefore disadvantageous to use too small coal, or form a stiff, tenacious slag.

Slags.—The form of slags, their fluidity and composition, is of so much importance to the metallurgist, that too much attention cannot be paid to this subject. We shall here confine our remarks to operations on a large scale. The substances of which slags are formed are chiefly silex, as the acid, and the metallic oxides, as bases or alkalies. Besides silex, we find, however, carbonic acid, chlorine, sulphuric acid, fluorine, phosphoric acid, and others in the slags; also sulphur and phosphorus. The alkalies are chiefly, oxide of iron, the oxides of manganese, lead, and copper; the alkaline earths are clay, and such fixed alkalies as are brought into the mixture accidentally, either by the ore or by the fuel. The substances which are added to an ore, in order to separate the metal, are fluxes, of which the number is very limited, because considerations of

economy compel the smelter to confine his selections to a small number of minerals and artificial ingredients. The most common fluxes in use are limestone, oxides of iron, and iron pyrites; siliceous or ferruginous slates and shales; clay; fluor-spar; black manganese; common salt; and a few other substances.

Fusibility of Slags.—The degree of heat at which slags melt is very different for different compositions, and ranges, as remarked before, between the boiling point of water and the highest attainable heat.

When it is the object to liquefy silex, the only agents by which to do it effectually are potash, soda, lime, oxide of lead, oxide of iron, and manganese. The presence of phosphoric acid or chlorine will not add to the capacity of these substances for dissolving silex, but as their combinations with metals are very fusible, they increase the fluidity of the slag: this alludes particularly to those slags which contain an abundance of metallic oxides. It cannot therefore be the object to dissolve silex by any such acid, but to cause the bases to be more fluid, and by that means compel the imperfectly dissolved silex to float more freely in the slags. The application of other acids than silex is limited to low heats only, because they generally evaporate before certain combinations or reductions can be effected. Protoxide of iron is the substance most generally used for dissolving silex, not because of its fusibility, but because it can be obtained abundantly in every place, its cheapness being the cause of its general use. Lime is next in importance to oxide of iron as a flux, but it does not form quite as fusible a slag with silex as iron or manganese; and metals

which cannot bear a high heat cannot be fluxed means of lime, magnesia, clay, and similar s stances. The fusibility of sulphurets is in m instances resorted to as a means to form slags, these cannot dissolve silex, and so far as the la substance is removed by sulphurets, it is only by being suspended in the fluid mass and rende more fluid. Yet all these heterogeneous substa may be united in a slag and form a perfectly f mass; and it is an important fact to be know metallurgical operations, that all compounds more fusible than single elements, and all slags crease in fusibility as their number of elem increase. This relates to metals and alloys as as to slags; and on this principle all operat must be conducted.

Lime and silex are not very easily melted: and silex show hardly any signs of melting; lime, clay, and silex melt very readily toget Protoxide of iron and silex form a fusible slag, when manganese, or lime, or soda, or potasl added, the fusibility of the slag is remarkably mented. In all cases the fusibility of a compo of various slags is greater than the mean fusibilit the whole, when considered as melted by th selves. If a compound of lime and silex melt 3000°, that of protoxide of iron and silex at 20 and that of a silicate of oxide of lead at 1000°, mean heat of the three, by which they will when mixed together, is not $\frac{3000+2000+1000}{3} = 20$ as their various degrees indicate, but it may be 1500°, and in this case even lower than that. greater the number of elements in a slag, the n fusible it becomes; it is therefore of the utr importance in all smelting operations to mult

the kind of ores: this produces fusible slags and fusible metals. In smelting iron, copper, lead, and all other metals, these rules are very well known by experienced smelters, and attended to; still they are not so much observed at the furnaces as they should be. As foreign matter has a decided influence upon some metals, it requires extreme caution in the selection of fluxes for certain kinds of metal. A flux which contains phosphorus will not in the least interfere with the quality of lead, but does great harm to iron, less to copper, and none at all to silver or gold. The presence of arsenic in an iron ore causes cast iron to be very short and hard, but it has a beneficial influence in making wrought iron: this substance cannot be removed from silver but by a tedious refining process: it acts in the same manner with lead. Sulphur is very injurious to iron and copper, but has no effect whatever on lead; silver and gold are more or less affected by its presence. The selection of fluxes must be therefore made with some discrimination and judgment in these respects.

Slags should be as fusible as the metal which is to be smelted with their assistance. If they are more refractory than the metal, the slag causes it to assume a heat by which more or less of it is evaporated. The slags must be so compounded that the flux which is added to the ore has more affinity for the foreign matter than for the oxide of the metal, or the metal itself which is to be produced. In the mean time the new compound formed by the flux and the foreign matter ought to be more fusible than the metal, so as to float down before the metal is perfectly melted. In some instances, namely, in those where the metal is to be carbonized, this rule

is not applicable, for it invariably removes the carbon from the metal. By means of such a fluid slag any kind of impurities may be removed from the metal when properly attended to. Another advantage of a fusible slag is the saving of fuel, for in this instance there is no need of raising the heat beyond the melting point of the metal.

Learned men have demonstrated that certain quantities of particular matter are required to form the most fusible compound. There is no doubt that certain laws regulate the formation of slags, which have evidently a strong bearing upon the results of metallurgical operations, but in smelting we cannot pretend to the niceties of the laboratory, and it is quite sufficient if we approach the laws strictly regulating this subject. When a slag is tough and tenacious it requires an alkali to make it more fluid; and if it is hard and brittle, inclined to chill, it requires an acid to flux it. In many cases the addition of other slags, so as to increase the quantity, causes the slag to be more fusible, and affords at the same time a protection to the metal. We will here allude to a few facts which indicate the importance of composition.

A slag taken from a blast-furnace for smelting iron, and which was composed of 50 silex, 17 alumina, 30 lime, and 3 protoxide of iron, melted by 2576°; but when the ingredients forming this slag were put together, finely powdered and mixed, and then exposed to heat, it required 3400° to form a slag of them. This shows how much more heat is required to melt a crude mixture than to melt a compound in which the particles are already arranged. It shows at the same time, that when the *flux* or a part of the flux is soluble in water, it ought

to be dissolved so as to bring it and the ore in close contact before exposing them to the influence of heat. Another composition of iron slags, which consisted of 58 silex, 6 clay, 2 protoxide of iron, 2 protoxide of manganese, 10 magnesia, and 22 lime, required the same heat as above for softening it, namely, 3400°. The heat by which it was kept in fusion was also similar to the above, namely, 2600°. Slag from a lead furnace, which was held in a fluid condition by a heat of 2400°, required 2650° for softening the ingredients of its composition. That slag was composed of 36·5 silex, 40·5 protoxide of iron, 8·5 alumina, 4· lime, 3· magnesia, 7·5 oxide of lead. A slag from a copper smelting furnace, for crude copper, contained 32·7 silex, 60·3 protoxide of iron, 7· alumina: this was held in a fluid state by 2400°, and required 2700° for melting the ingredients of which it was composed. We see here that the smaller the number of elements, the less readily a mixture melts.

In order to compare the above degrees of heat by which the slags are melted and kept in solution, with the degrees of heat by which metals melt, we annex the following: gold melts by 2000°, silver by 1870°, lead 630°, cast iron 2500° to 3000°, and platina 4580°.

General Reflections on Smelting.—In order to obtain a clear insight into smelting operations, it is necessary to analyze each process, and each part of that process, and observe what influence certain causes produce upon the metal. Here, as everywhere, it is difficult to reason from effect to cause, and therefore we follow the other way of arriving at conclusions. And if we apply the well-known laws of chemistry, with due regard to temperature, we

shall hardly ever fail of coming to correct conclusions in our experiments. Of the metals, copper has the strongest affinity for sulphur; then follow iron, tin, zinc, lead, silver, antimony, arsenic. As shown here, copper has a stronger affinity for sulphur than iron, and still copper is desulphuretted by iron, simply because of the mass of iron present: if the latter does not predominate, sulphur cannot be removed from copper by iron. This is no exception to the law for disengaging sulphur, for it is very well known that affinity is increased by mass. The alkaline earths and fixed alkalies have still more affinity for sulphur than these metals; and still they cannot remove the sulphur from most of these metals. Sulphurets of zinc, copper, or iron, cannot be decomposed by melted potash, at least no metal is produced to any extent: galena may be reduced entirely by it. The reason is, that metallic lead is more fusible than its sulphuret, and will separate at a lower heat than will melt the latter in potash. Sulphuret of copper, or iron, does not dissolve in potash. The latter absorbs some of the sulphur, but still leaves the metals with so much remaining as not to form pure metal. If the copper or iron were more fusible than the sulphuret suspended in the potash, it would coagulate, form globules, and separate in the metallic state. Some metals are not formed of sulphurets, even if an abundance of alkali is present, until carbon is brought in contact with them. Of this kind are lead, copper, and some others. Lime forms sulphates of lead, and lime of galena, and only a small portion of metal is separated; but if carbon is added sufficient to decompose these sulphates, nearly all the metal may be obtained from its sulphuret. In some instances the fusibility of

two united substances is resorted to in order to dissolve the one only. Sulphurets are not soluble in chlorides, neither are silicates, phosphates, or borates, and still a silicate with some chlorides is extremely fluid: a sulphuret may be perfectly mixed with chloride in the heat of a grate-fire; but as soon as the mass is cooled and water poured on, both separate. The cause is here obvious: sulphurets and chlorides are both soluble in heat, but not in water, in which only the latter is dissolved; and as no affinity exists between the two, both separate very readily. Still this compound performs in its smelted condition all the services of a slag. Carbonate of soda is no solvent for any sulphuret; it will melt, and the sulphuret will melt; both may be mixed together, but no decomposition ensues; but if carbon is introduced, so as to decompose the carbonic acid and liberate the caustic soda, it will absorb sulphur and produce metal in many cases, provided the metal is fusible in the heat which is applied. Copper may be reduced by these means. Iron cannot be melted, at least but very imperfectly, under a cover of potash or soda, because these substances will evaporate before the metal is melted. If carbon or sulphur is present in the iron, we may succeed somewhat better, but still imperfectly. If, however, a phosphate is present, either in the iron or in the flux, and also carbon sufficient to reduce the phosphate, iron may be melted easily under a cover of potash or soda. The metal, of course, which is the result of this operation, is very brittle, and a phosphuret, but it is chiefly iron. There is not the slightest difficulty in removing any quantity of impurities from a metal by means of matter which has more affinity for these substances than the

metal itself. This implies always the condition that the metal should be fusible at the same degree of heat, or nearly, at which the slag is fusible; also that it should not evaporate by that heat.

Sublimation.—Metals which are very volatile cannot be advantageously smelted; they are distilled, and in some cases sublimation is resorted to. There is not the slightest difficulty in smelting zinc, under a cover of carbonate of soda and potash, with carbon. But such a flux is expensive; and when not closely attended to while fluid, the loss is greater than the value of the metal obtained. It is for these reasons found to be cheaper to mix the oxide or carbonate of zinc with carbon, and distil it; or to mix the zinc blende with iron, and perform the same operation. The heat applied in these processes is by far higher than it is in smelting, and may cause the use of ten times as much fuel; still it is asserted that distillation is cheaper than smelting. Mercury is frequently produced by simple sublimation, without the addition of flux or coal; so also is arsenic. But in most instances, carbon and such substances as decompose the ore are added to it.

Refining.—Refining gold and silver is done in large or small reverberatory furnaces, of which the bottom forms a cupel. Copper or lead is refined in reverberatories by melting, and the addition of fluxes. Tin is purified in reverberatory furnaces, and also in iron pots, being stirred by wood so as to oxidize its impurities. Zinc is refined in the same manner and by the same means. Iron is refined in charcoal forges, in run-out fires, in reverberatories, and in puddling and reheating furnaces.

Liquefaction.—This is a delicate operation, but it is of great utility. Bismuth is obtained by liquefac-

tion. If the ore of this metal is heated with proper fluxes and in a proper apparatus, to a degree of heat which will melt the bismuth only, it will flow out from the ore, and form metal without the rocky and foreign matter being converted into a fusible slag. Antimony may be obtained by the same means, and in fact every kind of metal, provided the remains of the ore do not melt partially, so as to enclose grains of metal in a refractory, pasty cinder. As a mode of refining, it is chiefly used in separating silver from copper. When 11 parts of lead are melted with 3 parts of argentiferous copper, and this alloy is cooled slowly, the lead and silver may be made to flow out from the copper and lead; and the fluid lead thus obtained contains all the silver. The mode of operation in this case is generally to melt lead and copper perfectly, then cool it slowly. The copper and lead alloy, being the most refractory of the compound, will crystallize first, and the silver and lead last. When this combination of lead and silver, and the combination of lead and copper, is heated in a proper apparatus, the first will flow out at a certain heat and leave the other, which remains as a skeleton of the form of the whole body of alloy. Impure tin is refined on the same principle: when a pig of tin is laid on the highest part of the sloping hearth of a reverberatory furnace, and gently heated, the pure tin flows out first, and leaves behind a skeleton of iron, copper, and other metals, which do not melt at a low heat, and which are removed. This principle may be applied for the separation of metals by filtration: when, for instance, alloy is brought upon a body of sand, bone-ashes, lime, or similar matter, and melted, the moist fluid of the metals in the alloy will flow out first, pass through

the sand, and a skeleton of the refractory metals will remain.

Crystallization.—Most of the metals crystallize readily; all of them crystallize by proper treatment. Antimony and iron are particularly distinguished for their power of crystallization. The alloys of metals are not so much inclined to form regular bodies, at least not at the same degree of heat: for these reasons alloys may be separated from the pure metal. The fluid metals act here on the same principle as a salt dissolved in water. This property of metals and alloys has led to a valuable refining process for silver. When argentiferous lead is melted and then slowly cooled, the pure lead will sooner crystallize than the alloy of silver and lead, and a part of the pure lead may be gradually removed by a skimmer, or drainer. No perfect separation ensues here, for the coagulated lead still contains silver, and the richer the alloy the more silver is contained in the crystallized lead. Still, metal which contains but 10 ounces of silver in a ton of lead may be concentrated with little expense, to lead of 30 ounces of silver per ton. When these principles are intelligently applied, much may be expected of them in the way of refining metals.

Table of Squares, Cubes, and Fourth Power of Numbers.

Root.	Square.	Cube.	4th Power.	Root.	Square.	Cube.	4th Power.
1	1	1	1	7	49	343	2401
·1	1·21	1·331	1·4641	·1	50·41	357·911	2541·1681
·2	1·44	1·728	2·0736	·2	51·84	373·248	2687·3856
·3	1·69	2·197	2·8561	·3	53·29	389·017	2839·8241
·4	1·96	2·744	3·8416	·4	54·76	405·224	2998·6576
·5	2·25	3·375	5·0625	·5	56·25	421·875	3163·8625
·6	2·56	4·096	6·5536	·6	57·76	438·976	3346·2176
·7	2·89	4·913	8·3521	·7	59·29	456·533	3515·3041
·8	3·24	5·832	10·5876	·8	60·84	474·552	3701·4756
·9	3·61	6·859	13·0321	·9	62·41	493·039	3895·0081
2	4	8	16	8	64	512	4096
·1	4·41	9·261	19·4481	·1	65·61	531·441	4304·6721
·2	4·84	10·648	23·4256	·2	67·24	551·368	4521·2176
·3	5·29	12·167	27·8841	·3	68·89	571·787	4745·8221
·4	5·76	13·824	33·1776	·4	70·56	592·704	4979·5836
·5	6·25	15·625	39·0625	·5	72·25	614·125	5220·0625
·6	6·76	17·576	45·6976	·6	73·96	636·056	5470·0816
·7	7·29	19·683	53·1441	·7	75·69	658·503	5728·9761
·8	7·84	21·952	61·4656	·8	77·44	681·472	5996·9536
·9	8·41	24·389	70·7281	·9	79·21	704·969	6274·2141
3	9	27	81	9	81	729	6561
·1	9·61	29·791	92·3521	·1	82·81	753·571	6857·4961
·2	10·24	32·768	104·8576	·2	84·64	778·688	7173·9296
·3	10·89	35·937	118·5921	·3	86·49	804·357	7479·5201
·4	11·56	39·304	133·6336	·4	88·36	830·584	7807·4896
·5	12·25	42·875	150·0625	·5	90·25	857·375	8075·0525
·6	12·96	46·656	167·9616	·6	92·16	884·736	8493·6656
·7	13·69	50·653	187·4161	·7	94·09	912·673	8751·9281
·8	14·44	54·872	208·5136	·8	96·04	941·192	9231·6816
·9	15·21	59·319	231·3441	·9	98·01	970·299	9308·9601
4	16	64	256	10	100	1000	10000
·1	16·81	68·921	282·5761	·1	102·01	1030·301	10406·0401
·2	17·64	74·088	311 1696	·2	104·04	1061·208	10624·3216
·3	18·49	79·507	341·8801	·3	106·09	1092·727	11255·0881
·4	19·36	85·184	374·8096	·4	108·16	1124·864	11698·5856
·5	20·25	91·125	410·0625	·5	110·25	1157·625	12155·0625
·6	21·16	97·336	447·7456	·6	112·36	1191·016	12624·7696
·7	22·09	103·823	487·9681	·7	114·49	1225·043	13107·9601
·8	23·04	110·592	530·8416	·8	116·64	1259·712	13604·8896
·9	24·01	117·649	576·4801	·9	118·81	1295·029	14115·8161
5	25	125	625	11	121	1331	14641
·1	26·01	132·651	676·5201	·1	123·21	1367·631	15180·7041
·2	27·04	140·608	731·1616	·2	125·44	1404·928	15735·1936
·3	28·09	148·877	789·0481	·3	127·69	1442·897	16314·7361
·4	29·16	157·464	850·3056	·4	129·96	1481·544	16899·6016
·5	30·25	166·375	915·0625	·5	132·25	1520·875	17490·0625
·6	31·36	175·616	983·4496	·6	134·56	1560·896	18106·3936
·7	32·49	185·193	1055·6001	·7	136·89	1601·613	18749·9721
·8	33·64	195·112	1131·6496	·8	139·24	1643·032	19387·7776
·9	34·81	205·379	1211·7361	·9	141·61	1685·159	20153·3921
6	36	216	1296	12	144	1728	20736
·1	37·21	226·981	1384·5841	·1	146·41	1771·561	21345·8881
·2	38·44	238·328	1477·6336	·2	148·84	1815·848	22253·4556
·3	39·69	250·047	1575·2961	·3	151·29	1860·867	22898·6641
·4	40·96	262·144	1677·7216	·4	153·76	1906·624	23642·1376
·5	42·25	274·625	1785·0625	·5	156·25	1953·125	24414·0625
·6	43·56	287·496	1897·4736	·6	158·76	2000·376	25204·7376
·7	44·89	300·763	2015·1121	·7	161·29	2048·383	26011·6041
·8	46·24	314·432	2138·1376	·8	163·84	2097·152	26843·5456
·9	47·61	328·509	2266·7121	·9	166·41	2146·689	27692·388

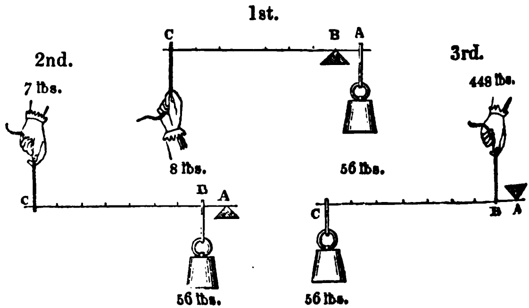
PRINCIPLES & PRACTICAL APPLICATIONS OF MECHANIC POWERS.

Mechanic Powers, or the Elements of Machinery, are certain simple mechanical arrangements whereby weights may be raised or resistances overcome with the exertion of less power or strength than is necessary without them.

They are usually accounted six in number, viz. the *lever*, the *wheel* and *axle*, the *pulley*, the *inclined plane*, the *wedge*, and the *screw;* but properly two of these comprise the whole, namely, the *lever* and *inclined plane*,—the wheel and axle being only a lever of the first kind, and the pulley a lever of the second,—the wedge and the screw being also similarly allied to that of the inclined plane: however, although such seems to be the case in these respects, yet they each require, on account of their various modifications, a peculiar rule of estimation adapted expressly to the different circumstances in which they are individually required to act.

1. THE LEVER.

Levers, according to mode of application, as the following,



are distinguished as being of the first, second, or third kind; and although levers of equal lengths produce different effects, the general principles of estimation in all are the same; namely, the power is to the weight or resistance, as the distance of the one end of the fulcrum is to the distance of the other end to the same point.

In the *first kind*, the power is to the resistance, as the distance A B is to the distance B C.

In the *second*, the power is to the resistance, as the distance A B is to that of A C; and,

In the *third*, the resistance is to the power, as the distance A B is to that of A C.

Rule, first kind.—Divide the longer by the shorter end of the lever from the fulcrum, and the quotient is the effective force that the power supplied is equal to.

Ex. 1. Let the handle of a pump equal 65 inches in length, and 10 inches from the shortest end to centre of motion; what is the amount of effective leverage thereby obtained?

$$65-10=55, \text{ and } \frac{55}{10}=5\tfrac{1}{2} \text{ to } 1.$$

Ex. 2. Required the situation of the fulcrum on which to rest a lever of 15 feet, so that $2\frac{1}{2}$ cwt. placed at one end may equipoise 30 cwt. at the other, the weight of the lever not being taken into account.

$\frac{15 \times 2\cdot5}{2\cdot5+30}=1\cdot154$ feet from the end on which the 30 cwt. is to be placed.

The common steelyard, or Roman balance, as represented in fig. 1, Plate D, is a lever of the first kind, and so divided that one weight w, moved to or from the axis of motion, will equipoise and there indicate the weight of any article required to be known.

It is by the second kind of lever that the greatest effect is obtained from any given amount of power; hence the propriety of the application of this principle to the working of force-pumps, and shearing of iron, as by the lever of a punching-press, &c.

Rule, second kind.—Divide the whole length of lever, or distance from power to fulcrum, by the distance from fulcrum to weight, and the quotient is the proportion of effect that the power is to the weight or resistance to be overcome.

Ex. Required the amount of effect or force produced by a power of 50 lbs. on the ram of a Bramah's pump, the length of the lever being 3 feet, and distance from ram to fulcrum $4\frac{1}{2}$ inches.

3 feet $=36$ inches, and $\frac{36}{4 \cdot 5}=8$, or the power and resistance are to each other as 8 to 1; hence $50 \times 8=400$ lbs. force upon the ram.

The lever on the safety-valve of a steam boiler is of the *third kind*, the action of the steam being the power, and the weight or spring-balance attached the resistance; but in such application the action of the lever's weight must also be taken into account, and may be simply ascertained by such means as represented in fig. 2, Plate D, where A is a *Salter's balance* attached to the lever by a light line, immediately at the point of pressure on the valve, and which, raised by hand or otherwise, will indicate the lever's action at that point.

This is perhaps the most frequent application of the third kind of lever to mechanical advantage, and that in which great nicety is required in estimation of effect: hence observe, as in other levers, there are three distinct points that require to be particularly attended to; namely, the *weight*, *fulcrum*, and *re-*

APPLICATIONS OF MECHANIC POWERS.

Fig. 1.

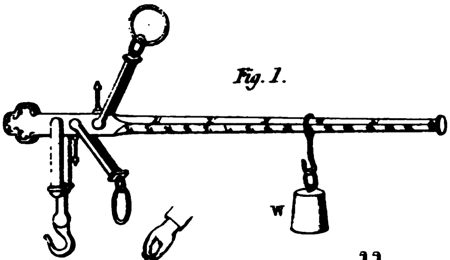
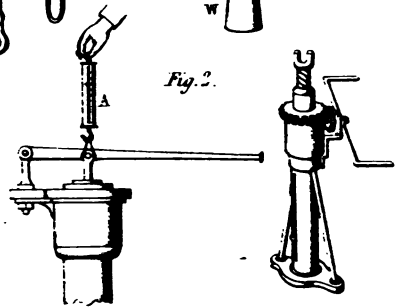
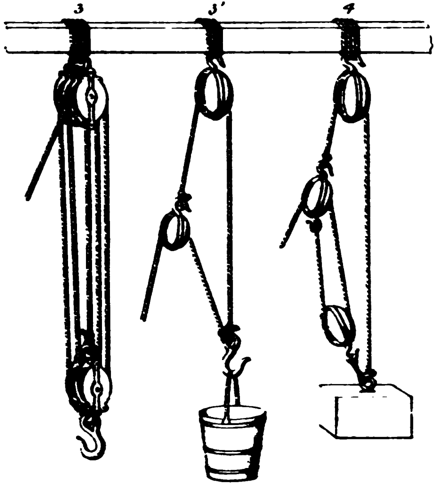


Fig. 2.

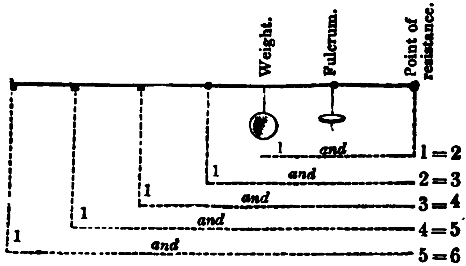




J. W. Lowry fc.

John Weale 59 High Holborn 1853.

sistance, as shown in the annexed diagram to illustrate this particular case.



Thus, suppose the weight to be placed on any one of the divisions, it is still the same weight, or 1; but because of the principle of the lever, the resistance is increased equal to the number of times the weight is distant from the fulcrum; consequently the action of the lever tends to press down the valve equal the sum of the weight and resistance, or the number of times the weight is distant from the resistance.

2. THE WHEEL AND PINION, OR CRANE.

The mechanical advantage of the wheel and axle, or crane, is as the velocity of the weight to the velocity of the power; and being only a modification of the first kind of lever, it of course partakes of the same principles.

1. *To determine the amount of effective power produced from a given power by means of a crane with known peculiarities.*

Rule.—Multiply together the diameter of the circle described by the winch, or handle, and the number of revolutions of the pinion to 1 of the wheel; divide the product by the barrel's diameter in equal terms

of dimensions, and the quotient is the effective power to 1 of exertive force.

Ex. Let there be a crane the winch of which describes a circle of 30 inches in diameter; the pinion makes 8 revolutions for 1 of the wheel, and the barrel is 11 inches in diameter; required the effective power in principle, also the weight that 36 lbs. would raise, friction not being taken into account.

$\frac{30 \times 8}{11} = 21{\cdot}8$ to 1 of exertive force; and $21{\cdot}8 \times 36 = 784{\cdot}8$ lbs.

2. *Given any two parts of a crane, to find the third, that shall produce any required proportion of mechanical effect.*

Rule.—Multiply the two given parts together, and divide the product by the required proportion of effect; the quotient is the dimensions of the other parts in equal terms of unity.

Ex. Suppose that a crane is required, the ratio of power to effect being as 40 to 1, and that a wheel and pinion 11 to 1 is unavoidably compelled to be employed, also the throw of each handle to be 16 inches; what must be the barrel's diameter on which the rope or chain must coil?

$16 \times 2 = 32$ inches diameter described by the handle.

And $\frac{32 \times 11}{40} = 8{\cdot}8$ inches, the barrel's diameter.

3. THE PULLEY.

The principle of the pulley, or more practic the block and tackle, is the distribution of weigh various points of support; the mechanical advar derived depending entirely upon the flexibility tension of the rope, and the number of pulle sheives in the lower or rising block: hence, by l and tackle of the usual kind, as shown in fig. 3,

the power is to the weight as the number of cords attached to the lower block; whence the following rules.

1. Divide the weight to be raised by the number of cords leading *to*, *from*, or *attached* to the lower block; and the quotient is the power required to produce an equilibrium, provided friction did not exist.

2. Divide the weight to be raised by the power to be applied; the quotient is the number of sheives in, or cords attached to the rising block.

Ex. Required the power necessary to raise a weight of 3000 lbs. by a four and five-sheived block and tackle, the four being the moveable or rising block.

Necessarily there are nine cords leading to and from the rising block.

Consequently $\frac{3000}{9}=333$ lbs., the power required.

Ex. 2. I require to raise a weight of 1 ton 18 cwt., or 4256 lbs.; the amount of my power to effect this object being 500 lbs., what kind of block and tackle must I of necessity employ?

$\frac{4256}{500}=8{\cdot}51$ cords; of necessity there must be 4 sheives or 9 cords in the rising block.

As the effective power of the crane may, by additional wheels and pinions, be increased to any required extent, so may the pulley and tackle be similarly augmented by purchase upon purchase; two of the most useful of such applications being represented in figs. 3 and 4, Plate D, the first of which is known by the term *runner* and *tackle*, and the second by that of *Spanish burton*.

4. THE INCLINED PLANE.

The *inclined plane* is properly the second elementary power, and may be defined the lifting of a load by regular instalments. In principle it consists of any right line not coinciding with, but laying in a sloping direction to, that of the horizon; the standard of comparison of which commonly consists in referring the rise to so many parts in a certain length or distance, as 1 in 100, 1 in 200, &c.,—the first number representing the perpendicular height, and the latter the horizontal length in attaining such height, both numbers being of the same denomination, unless otherwise expressed; but it may be necessary to remark, that the inclination of a plane, the sine of inclination, the height per mile, or the height for any length, the ratio, &c., are all synonymous terms.

The advantage gained by the inclined plane, when the power acts in a parallel direction to the plane, is as the length to the height or angle of inclination: hence the rule. Divide the weight by the ratio of inclination, and the quotient equal the power that will just support that weight upon the plane. Or, multiply the weight by the height of the plane, and divide by the length,—the quotient is the power.

Ex. Required the power or equivalent weight capable of supporting a load of 350 lbs. upon a plane of 1 in 12, or 3 feet in height and 36 feet in length.

$$\frac{350}{12} = 29{\cdot}16 \text{ lbs., or } \frac{350 \times 3}{36} = 29{\cdot}16 \text{ lbs. power, as before.}$$

Note.—The weight multiplied by the length of the base, and the product divided by the length of the incline, the quotient equal the pressure or downward weight upon the incline.

Table showing the Resistance opposed to the Motion of Carriages on different Inclinations of Ascending or Descending Planes, whatever part of the insistent weight they are drawn by.

Tens.		Hundreds.								
		100	200	300	400	500	600	700	800	900
		·01	·005	·00333	·0025	·002	·00167	·00143	·00125	·00111
10	·1	·00909	·00476	·00322	·00244	·00196	·00164	·00141	·00123	·0011
20	·05	·00833	·00454	·00312	·00238	·00192	·00161	·00139	·00122	·00109
30	·0333	·00769	·00435	·00303	·00232	·00189	·00159	·00137	·0012	·00107
40	·025	·00714	·00417	·00294	·00227	·00185	·00156	·00135	·00119	·00106
50	·02	·00667	·004	·00286	·00222	·00182	·00154	·00133	·00118	·00105
60	·0166	·00625	·00385	·00278	·00217	·00178	·00151	·00131	·00116	·00104
70	·0143	·00588	·0037	·0027	·00213	·00175	·00149	·0013	·00115	·00103
80	·0125	·00555	·00357	·00263	·00208	·00172	·00147	·00128	·00114	·00102
90	·0111	·00526	·00345	·00256	·00204	·00169	·00145	·00126	·00112	·00101

Vote.—Although this Table has been calculated particularly carriages on railway inclines, it may with equal propriety be lied to any other incline, the amount of traction on a level ıg known.

Application of the preceding Table.

1. What weight will a tractive power of 150 lbs. draw up an incline of 1 in 340, the resistance on the level being estimated at $\frac{1}{240}$th part of the insistent weight?

In a line with 40 in the left-hand column and under
200 is . . . . ·00417
Also in the same line and under 300 is . . . . ·00294

Added together = ·00711

Then $\frac{150}{\cdot 00711} = 21097$ lbs. weight drawn up the plane.

2. What weight would a force of 150 lbs. draw down the same plane, the friction on the level being the same as before?

Friction on the level = ·00417
Gravity of the plane = ·00294 subtract

= ·00123

And $\frac{150}{\cdot 00123} = 121915$ lbs. weight drawn down the plane.

Example of incline when velocity is taken into account.

A power of 230 lbs., at a velocity of 75 feet per minute, is to be employed for moving weights up an inclined plane 12 feet in height and 163 feet in length, the least velocity of the weight to be 8 feet per minute; required the greatest weight that the power is equal to.

$$\frac{230 \times 75 \times 163}{12 \times 8} = \frac{2811750}{96} = 29288 \text{ lbs., or } 13\cdot 25 \text{ tons.}$$

TABLE OF INCLINED PLANES,

Showing the ascent or descent per yard, and the corresponding ascent or descent per chain, per mile; and also the ratio.

Per yard.		Per chain.	Per mile.	Ratio.	Per yard.		Per chain.	Per mile.	Ratio.
In parts of an in.	In decls. of an inch.	Inches.	Feet.	One in	In parts of an in.	In decls. of an inch.	Inches.	Feet.	One in
$\frac{1}{64}$	·0156	·344	2·29	2304	$\frac{7}{16}$	·4375	9·625	64·17	82
$\frac{1}{48}$	·0208	·458	3·06	1728	$\frac{1}{2}$	·5	11	73·33	72
$\frac{1}{32}$	·0312	·687	4·58	1152	$\frac{9}{16}$	·5625	12·375	82·5	64
$\frac{1}{24}$	·0417	·917	6·11	864	$\frac{7}{12}$	·5833	12·833	85·56	62
$\frac{1}{16}$	·0625	1·375	9·17	576	$\frac{3}{5}$	·6	13·2	88	60
$\frac{1}{12}$	·0833	1·833	12·22	432	$\frac{5}{8}$	·625	13·75	91·67	58
$\frac{1}{10}$	·1	2·2	14·67	360	$\frac{2}{3}$	·6667	14·667	97·78	54
$\frac{1}{8}$	·125	2·75	18·33	288	$\frac{11}{16}$	·6875	15·125	100·83	52
$\frac{1}{6}$	·1667	3·667	24·44	216	$\frac{7}{10}$	·7	15·4	102·67	51
$\frac{3}{16}$	·1875	4·125	27·50	192	$\frac{3}{4}$	·75	16·5	110	48
$\frac{1}{5}$	·2	4·4	29·33	180	$\frac{4}{5}$	·8	17·6	117·33	45
$\frac{1}{4}$	·25	5·5	36·67	144	$\frac{13}{16}$	·8125	17·875	119·17	44
$\frac{3}{10}$	·3	6·6	44	120	$\frac{5}{6}$	·8333	18·333	122·22	43
$\frac{5}{16}$	·3125	6·875	45·83	115	$\frac{7}{8}$	·875	19·25	128·33	41
$\frac{1}{3}$	·3333	7·333	48·89	108	$\frac{9}{10}$	·9	19·8	132	40
$\frac{3}{8}$	·375	8·25	55	96	$\frac{11}{12}$	·9167	20·167	134·44	39
$\frac{2}{5}$	·4	8·8	58·67	20	$\frac{15}{16}$	·9375	20·625	137·5	38
$\frac{5}{12}$	·4167	9·167	61·11	86	1	1	22	146·67	36

THE WEDGE.

The wedge is a double inclined plane, consequently its principles are the same: Hence when two bodies are forced asunder by means of the wedge in a direction parallel to its head,—Multiply the resisting power by half the thickness of the head or back of the wedge, and divide the product by the length of one of its inclined sides; the quotient is the force equal to the resistance.

Ex. The breadth of the back or head of a wedge being 3 inches, and its inclined sides each 10 inches, required the power necessary to act upon the wedge so as to separate two substances whose resisting force is equal to 150 lbs.

$$\frac{150 \times 1 \cdot 5}{10} = 22 \cdot 5 \text{ lbs.}$$

Note.—When only one of the bodies is moveable, the whole breadth of the wedge is taken for the multiplier.

THE SCREW.

The screw, in principle, is that of an inclined plane wound around a cylinder which generates a spiral of uniform inclination, each revolution producing a rise or traverse motion equal to the pitch of the screw, or distance between two consecutive threads,—the pitch being the height or angle of inclination, and the circumference the length of the plane when a lever is not applied; but the lever being a necessary qualification of the screw, the circle which it describes is taken, instead of the screw's circumference, as the length of the plane: hence the mechanical advantage is, as the circumference of the circle described by

the lever where the power acts, is to the pitch of the screw, so is the force to the resistance in principle.

Ex. 1. Required the effective power obtained by a screw of $\frac{7}{8}$ inch pitch, and moved by a force equal to 50 lbs. at the extremity of a lever 30 inches in length.

$$\frac{30 \times 2 \times 3{\cdot}1416 \times 50}{{\cdot}875} = 10760 \text{ lbs.}$$

Ex. 2. Required the power necessary to overcome a resistance equal to 7000 lbs. by a screw of $1\frac{1}{4}$ inch pitch, and moved by a lever 25 inches in length.

$$\frac{7000 \times 1{\cdot}25}{25 \times 2 \times 3{\cdot}1416} = 55{\cdot}73 \text{ lbs. power.}$$

In the case of a screw acting on the periphery of a toothed wheel, the power is to the resistance, as the product of the circle's circumference described by the winch or lever, and radius of the wheel, to the product of the screw's pitch, and radius of the axle, or point whence the power is transmitted; but observe, that if the screw consist of more than one helix or thread, the apparent pitch must be increased so many times as there are threads in the screw. *Hence, to find what weight a given power will equipoise:*

Rule.—Multiply together the radius of the wheel, the length of the lever at which the power acts, the magnitude of the power, and the constant number 6·2832; divide the product by the radius of the axle into the pitch of the screw, and the quotient is the weight that the power is equal to.

Ex. What weight will be sustained in equilibrio by a power of 100 lbs. acting at the end of a lever 24 inches in length, the radius of the axle, or point whence the power is transmitted, being 8 inches, the

radius of the wheel 14 inches, the screw consisting of a double thread, and the apparent pitch equal ⅝ of an inch?

$$\frac{14 \times 24 \times 100 \times 6{\cdot}2832}{{\cdot}625 \times 2 \times 8} = 21111{\cdot}55 \text{ lbs., or } 9{\cdot}4 \text{ tons, the power sustained.}$$

Note.—It is estimated that about one-third more power must be added to overcome the friction of the screw when loaded, than is necessary to constitute a balance between power and weight.

OF CONTINUOUS CIRCULAR MOTION.

In mechanics, circular motion is transmitted by means of *wheels*, *drums*, or *pulleys*; and accordingly as the driving and driven are of equal or unequal diameters, so are equal or unequal velocities produced: hence the principle on which the following rules are founded.

1. WHEN TIME IS NOT TAKEN INTO ACCOUNT.

Rule.—Divide the greater diameter, or number of teeth, by the lesser diameter, or number of teeth, and the quotient is the number of revolutions the lesser will make for 1 of the greater.

Ex. How many revolutions will a pinion of 20 teeth make for 1 of a wheel with 125?

$$125 \div 20 = 6{\cdot}25, \text{ or } 6\tfrac{1}{4} \text{ revolutions.}$$

Note.—Intermediate wheels of whatever diameters, so as to connect communication at any required distance apart, cause no variation of velocity more than otherwise would result were the first and last in immediate contact.

To find the number of revolutions of the last, to 1 of the first, in a train of wheels and pinions.

Rule.—Divide the product of all the teeth in the driving, by the product of all the teeth in the driven, and the quotient equal the ratio of velocity required.

Ex. 1. Required the ratio of velocity of the last, to 1 of the first, in the following train of wheels and pinions; viz., *pinions driving,*—the first of which contains 10 teeth, the second 15, and third 18;—*wheels driven,* —first 15 teeth, second 25, and third 32.

$$\frac{10 \times 15 \times 18}{15 \times 25 \times 32} = \cdot 225$$ of a revolution the wheel will make to 1 of the pinion.

Ex. 2. A wheel of 42 teeth giving motion to one of 12, on which shaft is a pulley of 21 inches diameter, driving one of 6; required the number of revolutions of the last pulley to 1 of the first wheel.

$$\frac{42 \times 21}{12 \times 6} = 12\cdot 25, \text{ or } 12\tfrac{1}{4} \text{ revolutions.}$$

Note.—Where increase or decrease of velocity is required to be communicated by wheel-work, it has been demonstrated that the number of teeth on each pinion should not be less than 1 to 6 of its wheel, unless there be some other important reason for a higher ratio.

2. WHEN TIME MUST BE REGARDED.

Rule.—Multiply the diameter, or number of teeth in the driver, by its velocity in any given time, and divide the product by the required velocity of the driven; the quotient equal the number of teeth, or diameter of the driven, to produce the velocity required.

Ex. 1. If a wheel containing 84 teeth makes 20 revolutions per minute, how many must another contain to work in contact, and make 60 revolutions in the same time?

$$\frac{84 \times 20}{60} = 28 \text{ teeth.}$$

Ex. 2. From a shaft making 45 revolutions per minute, and with a pinion 9 inches diameter at the pitch line, I wish to transmit motion at 15 revolutions per minute; what at the pitch line must be the diameter of the wheel?

$$\frac{45 \times 9}{15} = 27 \text{ inches.}$$

Ex. 3. Required the diameter of a pulley to make 16 revolutions in the same time as one of 24 inches making 36.

$$\frac{24 \times 36}{16} = 54 \text{ inches.}$$

The distance between the centres and velocities of two wheels being given, to find their proper diameters.

Rule.—Divide the greatest velocity by the least; the quotient is the ratio of diameter the wheels must bear to each other. Hence, divide the distance between the centres by the ratio plus 1; the quotient equal the radius of the smaller wheel; and subtract the radius thus obtained from the distance between the centres; the remainder equal the radius of the other.

Ex. The distance of two shafts from centre to centre is 50 inches, and the velocity of the one 25 revolutions per minute, the other is to make 80 in the same time; the proper diameters of the wheels at the pitch lines are required.

$80 \div 25 = 3{\cdot}2$, ratio of velocity, and $\frac{50}{3{\cdot}2 + 1} = 11{\cdot}9$, the radius of the smaller wheel; then $50 - 11{\cdot}9 = 38{\cdot}1$, radius of larger; their diameters are $11{\cdot}9 \times 2 = 23{\cdot}8$, and $38{\cdot}1 \times 2 = 76{\cdot}2$ inches.

To obtain or diminish an accumulated velocity by means of wheels and pinions, or wheels, pinions, and pulleys, it is necessary that a proportional ratio of velocity should exist, and which is simply thus at-

tained:—Multiply the given and required velocities together, and the square root of the product is the mean or proportionate velocity.

Ex. Let the given velocity of a wheel containing 54 teeth equal 16 revolutions per minute, and the given diameter of an intermediate pulley equal 25 inches, to obtain a velocity of 81 revolutions in a machine; required the number of teeth in the intermediate wheel, and diameter of the last pulley.

$\sqrt{81 \times 16} = 36$ mean velocity.

$\frac{54 \times 16}{36} = 24$ teeth, and $\frac{25 \times 36}{81} = 11{\cdot}1$ inches, diameter of pulley.

To determine the proportion of wheels for screw cutting by a Lathe.

In a lathe properly adapted, screws to any degree of pitch, or number of threads in a given length, may be cut by means of a leading screw of any given pitch, accompanied with change wheels and pinions; course pitches being effected generally by means of one wheel and one pinion with a *carrier*, or *intermediate wheel*, which cause no variation or change of motion to take place: hence the following

Rule.—Divide the number of threads in a given length of the screw which is to be cut, by the number of threads in the same length of the leading screw attached to the lathe; and the quotient is the ratio that the wheel on the end of the screw must bear to that on the end of the lathe spindle.

Ex. Let it be required to cut a screw with 5 threads in an inch, the leading screw being of $\frac{1}{2}$ inch pitch, or containing 2 threads in an inch; what must be the ratio of wheels applied?

$5 \div 2 = 2{\cdot}5$, the ratio they must bear to each other.

Then suppose a pinion of 40 teeth be fixed upon for the spindle,—

$40 \times 2{\cdot}5 = 100$ teeth for the wheel on the end of the screw.

But screws of a greater degree of fineness than about 8 threads in an inch are more conveniently cut by an additional wheel and pinion, because of the proper degree of velocity being more effectively attained; and these, on account of revolving upon a stud, are commonly designated the *stud-wheels*, or *stud-wheel* and *pinion;* but the mode of calculation and ratio of screw are the same as in the preceding rule;—hence, all that is further necessary is to fix upon any 3 wheels at pleasure, as those for the spindle and stud-wheels,—then multiply the number of teeth in the spindle-wheel by the ratio of the screw, and by the number of teeth in that wheel or pinion which is in contact with the wheel on the end of the screw; divide the product by the stud-wheel in contact with the spindle-wheel, and the quotient is the number of teeth required in the wheel on the end of the leading screw.

Ex. Suppose a screw is required to be cut containing 25 threads in an inch, the leading screw as before having 2 threads in an inch, and that a wheel of 60 teeth is fixed upon for the end of the spindle, 20 for the pinion in contact with the screw-wheel, and 100 for that in contact with the wheel on the end of the spindle;—required the number of teeth in the wheel for the end of the leading screw.

$$25 \div 2 = 12{\cdot}5, \text{ and } \frac{60 \times 12{\cdot}5 \times 20}{100} = 150 \text{ teeth.}$$

Or suppose the spindle and screw-wheels to be those fixed upon, also any one of the stud-wheels, to find the number of teeth in the other.

$$\frac{60 \times 12{\cdot}5}{150 \times 100} = 20 \text{ teeth, or } \frac{60 \times 12{\cdot}5 \times 20}{150} = 100 \text{ teeth.}$$

'able of Change Wheels for Screw Cutting, the leading screw being of ½ inch pitch, or containing 2 threads in an inch.

inch of screw.	Numb. of teeth in		Number of threads in inch of screw.	Number of teeth in				Number of threads in inch of screw.	Number of teeth in			
	Lathe spindle-wheel.	Leading screw-wheel.		Lathe spindle-wheel.	Wheel in contact with spindle-wheel.	Pinion in contact with screw-wheel.	Leading screw-wheel.		Lathe spindle-wheel.	When in contact with spindle-wheel.	Pinion in contact with screw-wheel.	Leading screw-wheel.
1	80	40	8¼	40	55	20	60	19	50	95	20	100
1¼	80	50	8½	90	85	20	90	19½	80	120	20	130
1½	80	60	8¾	60	70	20	75	20	60	100	20	120
1¾	80	70	9½	90	90	20	95	20¼	40	90	20	90
2	80	90	9¾	40	60	20	65	21	80	120	20	140
2¼	80	90	10	60	75	20	80	22	60	110	20	120
2½	80	100	10½	50	70	20	75	22½	80	120	20	150
2¾	80	110	11	60	55	20	120	22¾	80	130	20	140
3	80	120	12	90	90	20	120	23¾	40	95	20	100
3¼	80	130	12¾	60	85	20	90	24	65	120	20	130
3½	80	140	13	90	90	20	130	25	60	100	20	150
3¾	80	150	13½	60	90	20	90	25½	30	85	20	90
4	40	80	13¾	80	100	20	110	26	70	130	20	140
4¼	40	85	14	90	90	20	140	27	40	90	20	120
4½	40	90	14¼	60	90	20	95	27½	40	100	20	110
4¾	40	95	15	90	90	20	150	28	75	140	20	150
5	40	100	16	60	80	20	120	28½	30	90	20	95
5½	40	110	16¼	80	100	20	130	30	70	140	20	150
6	40	120	16½	80	110	20	120	32	30	80	20	120
6½	40	130	17	45	85	20	90	33	40	110	20	120
7	40	140	17½	80	100	20	140	34	30	85	20	120
7½	40	150	18	40	60	20	120	35	60	140	20	150
8	30	120	18¾	80	100	20	150	36	30	90	20	120

Table by which to determine the Number of Teeth, or Pitch of Small Wheels, by what is commonly called the Manchester principle.

Diametral pitch.	Circular pitch.	Diametral pitch.	Circular pitch.
3	1·047	9	·349
4	·785	10	·314
5	·628	12	·262
6	·524	14	·224
7	·449	16	·196
8	·393	20	·157

Ex. 1. Required the number of teeth that a wheel of 16 inches diameter will contain of a 10 pitch.

$16 \times 10 = 160$ teeth, and the circular pitch = 314 inch.

Ex. 2. What must be the diameter of a wheel for a 9 pitch of 126 teeth?

$\frac{126}{9} = 14$ inches diameter, circular pitch ·349 inch.

Note.—The pitch is reckoned on the diameter of the wheel instead of the circumference, and designated wheels of 8 pitch, 12 pitch, &c.

Strength of the Teeth of Cast-Iron Wheels at a given velocity.

Pitch of teeth in inches.	Thickness of teeth in inches.	Breadth of teeth in inches.	Strength of teeth in horse-power, at			
			3 ft. per second.	4 ft. per second.	6 ft. per second.	8 ft. per second.
3·99	1·9	7·6	20·57	27·43	41·14	54·85
3·78	1·8	7·2	17·49	23·32	34·98	46·64
3·57	1·7	6·8	14·73	19·65	29·46	39·28
3·36	1·6	6·4	12·28	16·38	24·56	32·74
3·15	1·5	6	10·12	13·50	20·24	26·98
2·94	1·4	5·6	8·22	10·97	16·44	21·92
2·73	1·3	5·2	6·58	8·78	13·16	17·54
2·52	1·2	4·8	5·18	6·91	10·36	13·81
2·31	1·1	4·4	3·99	5·32	7·98	10·64
2·1	1·0	4	3·00	4·00	6·00	8·00
1·89	·9	3·6	2·18	2·91	4·36	5·81
1·68	·8	3·2	1·53	2·04	3·06	3·08
1·47	·7	2·8	1·027	1·37	2·04	2·72
1·26	·6	2·4	·64	·86	1·38	1·84
1·05	·5	2	·375	·50	·75	1·00

teeth at a given pitch.

Number of teeth.	Pitch of the teeth in inches.																											
	1 inch		1⅛		1¼		1⅜		1½		1⅝		1¾		1⅞		2 inch		2⅛		2¼		2½		2¾		3 inch	
	Diameter at the pitch circle in feet and inches.																											
10	0	3¼	0	3⅝	0	4	0	4½	0	4⅞	0	5¼	0	5⅝	0	6	0	6½	0	6⅞	0	7¼	0	8	0	8⅞	0	9⅝
11	0	3½	0	4	0	4⅜	0	5	0	5⅜	0	5¾	0	6¼	0	6⅝	0	7	0	7½	0	7⅞	0	8¾	0	9¾	0	10⅝
12	0	3⅞	0	4⅜	0	4⅞	0	5⅜	0	5⅞	0	6⅜	0	6¾	0	7⅛	0	7⅝	0	8⅛	0	8⅝	0	9⅝	0	10⅝	0	11½
13	0	4⅛	0	4¾	0	5¼	0	5¾	0	6¼	0	6⅞	0	7⅜	0	7⅞	0	8⅜	0	8⅞	0	9⅜	0	10⅜	0	11½	1	0½
14	0	4½	0	5	0	5⅝	0	6¼	0	6¾	0	7⅜	0	7⅞	0	8½	0	9	0	9½	0	10	0	11¼	1	0⅜	1	1½
15	0	4⅞	0	5⅜	0	6	0	6⅝	0	7¼	0	7⅞	0	8½	0	9	0	9⅝	0	10¼	0	10¾	1	0	1	1¼	1	2⅜
16	0	5⅛	0	5¾	0	6⅜	0	7	0	7⅝	0	8⅜	0	9	0	9⅝	0	10¼	0	10⅞	0	11½	1	0¾	1	2	1	3⅜
17	0	5½	0	6⅛	0	6¾	0	7½	0	8¼	0	8⅞	0	9⅝	0	10¼	0	10⅞	0	11½	1	0¼	1	1½	1	2⅞	1	4¼
18	0	5¾	0	6½	0	7⅛	0	8	0	8⅝	0	9⅜	0	10	0	10¾	0	11½	1	0¼	1	0⅞	1	2⅜	1	3¾	1	5¼
19	0	6	0	6⅞	0	7½	0	8⅜	0	9⅛	0	9⅞	0	10⅝	0	11⅜	1	0⅛	1	0⅞	1	1⅝	1	3⅛	1	4⅝	1	6¼
20	0	6⅜	0	7⅛	0	8	0	8⅞	0	9⅝	0	10⅜	0	11¼	1	0	1	0¾	1	1½	1	2⅜	1	4	1	5½	1	7⅛
21	0	6¾	0	7½	0	8⅜	0	9¼	0	10	0	11	0	11¾	1	0½	1	1½	1	2¼	1	3	1	4¾	1	6⅜	1	8⅛
22	0	7	0	7⅞	0	8¾	0	9⅝	0	10⅝	0	11½	1	0⅜	1	1⅛	1	2	1	2⅞	1	3¾	1	5½	1	7¼	1	9
23	0	7⅜	0	8¼	0	9⅛	0	10	0	11	1	0	1	0⅞	1	1¾	1	2⅝	1	3½	1	4½	1	6⅜	1	8	1	10
24	0	7⅝	0	8⅝	0	9½	0	10½	0	11½	1	0½	1	1½	1	2⅜	1	3⅜	1	4¼	1	5¼	1	7⅛	1	9	1	10⅞
25	0	8	0	9	0	10	0	11	1	0	1	1	1	2	1	2⅞	1	3⅞	1	4⅞	1	6	1	8	1	9⅞	1	11⅞
26	0	8¼	0	9¼	0	10⅜	0	11½	1	0½	1	1½	1	2½	1	3½	1	4½	1	5½	1	6⅝	1	8¾	1	10¾	2	0⅞
27	0	8⅝	0	9⅝	0	10¾	0	11⅞	1	1	1	2	1	3	1	4⅛	1	5¼	1	6¼	1	7⅜	1	9½	1	11⅝	2	1¾
28	0	9	0	10	0	11¼	1	0¼	1	1¼	1	2½	1	3⅝	1	4⅝	1	5¾	1	6⅞	1	8	1	10¼	2	0½	2	2¾
29	0	9¼	0	10⅜	0	11⅝	1	0¾	1	1⅞	1	3	1	4⅛	1	5⅜	1	6½	1	7⅝	1	8¾	1	11⅛	2	1⅜	2	3¾

Table of the Diameters of Wheels—continued.

Number of teeth.	1 inch		1⅛		1¼		1⅜		1½		1⅝		1¾		1⅞		2 inch		2⅛		2¼		2½		2¾		3 inch	
	Diameter at the pitch circle in feet and inches.																											
30	0	9½	0	10¾	1	0	1	1⅛	1	2⅜	1	3½	1	4¾	1	6	1	7⅛	1	8¼	1	9½	2	0	2	2¼	2	4⅝
31	0	9⅞	0	11⅛	1	0⅜	1	1⅝	1	2⅞	1	4	1	5⅜	1	6½	1	7¾	1	9	1	10¼	2	0¾	2	3⅛	2	5⅝
32	0	10¼	0	11½	1	0¾	1	2	1	3⅜	1	4⅝	1	5⅞	1	7⅛	1	8⅜	1	9⅝	1	11	2	1½	2	4	2	6⅝
33	0	10½	0	11⅞	1	1⅛	1	2½	1	3¾	1	5⅛	1	6½	1	7¾	1	9	1	10⅜	1	11⅝	2	2¼	2	4⅞	2	7½
34	0	10⅞	1	0⅛	1	1⅝	1	3	1	4¼	1	5⅝	1	7	1	8⅜	1	9⅝	1	11	2	0⅜	2	3	2	5¾	2	8½
35	0	11⅛	1	0⅝	1	2	1	3⅜	1	4¾	1	6⅛	1	7½	1	9	1	10⅜	1	11¾	2	1	2	3⅞	2	6⅝	2	9½
36	0	11½	1	1	1	2⅜	1	3¾	1	5¼	1	6⅝	1	8	1	9½	1	10⅞	2	0⅜	2	2	2	4⅝	2	7½	2	10⅜
37	0	11¾	1	1¼	1	2¾	1	4¼	1	5⅝	1	7¼	1	8⅝	1	10	1	11½	2	1	2	2½	2	5½	2	8⅜	2	11⅜
38	1	0⅛	1	1⅝	1	3¼	1	4⅝	1	6¼	1	7⅝	1	9¼	1	10¾	2	0¼	2	1¾	2	3¼	2	6¼	2	9¼	3	0¼
39	1	0⅜	1	2	1	3½	1	5	1	6⅝	1	8¼	1	9¾	1	11⅜	2	0⅞	2	2⅜	2	4	2	7	2	10⅛	3	1¼
40	1	0¾	1	2⅜	1	4	1	5½	1	7⅛	1	8¾	1	10⅜	1	11⅞	2	1½	2	3	2	4⅝	2	7⅞	2	10¾	3	2¼
41	1	1	1	2¾	1	4⅜	1	6	1	7⅝	1	9¼	1	10⅞	2	0½	2	2⅛	2	3¾	2	5⅜	2	8⅝	2	11⅞	3	3¼
42	1	1⅜	1	3	1	4¾	1	6⅜	1	8	1	9¾	1	11½	2	1	2	2¾	2	4½	2	6	2	9½	3	0¾	3	4⅛
43	1	1⅝	1	3½	1	5⅛	1	6⅞	1	8⅝	1	10¼	2	0	2	1⅝	2	3⅜	2	5	2	6¾	2	10¼	3	1⅝	3	5
44	1	2	1	3¾	1	5⅝	1	7¼	1	9	1	10¾	2	0½	2	2¼	2	4	2	5¾	2	7½	2	11	3	2½	3	6
45	1	2⅜	1	4⅛	1	6	1	7¾	1	9½	1	11⅜	2	1	2	2⅞	2	4⅝	2	6½	2	8¼	2	11¾	3	3⅜	3	7
46	1	2⅝	1	4½	1	6⅜	1	8⅛	1	10	1	11⅞	2	1⅝	2	3½	2	5¼	2	7⅛	2	9	3	0⅝	3	4¼	3	7⅞

54	1	5⅛	1	7⅜	1	9½	1	11⅝	2	1¾	2	3⅞	2	6	2	8¼	2	10⅜	3	0½	3	2⅝	3	7	3	11	4	3½
55	1	5½	1	7¾	1	9⅞	2	0	2	2¼	2	4½	2	6⅝	2	8⅞	2	11	3	1¼	3	3½	3	7¾	4	0⅛	4	4½
56	1	5⅞	1	8⅛	1	10¼	2	0½	2	2¾	2	4⅞	2	7⅛	2	9⅜	2	11⅝	3	1⅞	3	4⅛	3	8½	4	1	4	5½
57	1	6⅛	1	8½	1	10⅝	2	0⅞	2	3¼	2	5¼	2	7¾	2	10	3	0¼	3	2½	3	4⅞	3	9⅜	4	1⅞	4	6⅜
58	1	6½	1	8¾	1	11	2	1⅜	2	3⅝	2	6	2	8¼	2	10⅝	3	0⅞	3	3¼	3	5½	3	10⅛	4	2¾	4	7⅜
59	1	6¾	1	9⅛	1	11½	2	1⅞	2	4⅛	2	6½	2	8⅞	2	11¼	3	1½	3	4	3	6¼	3	11⅛	4	3⅝	4	8⅜
60	1	7⅛	1	9⅜	1	11⅞	2	2¼	2	4⅝	2	7	2	9⅜	2	11¾	3	2¼	3	4⅝	3	7	3	11¾	4	4½	4	9¼
61	1	7½	1	9⅞	2	0¼	2	2¾	2	5¼	2	7½	2	10	3	0⅜	3	2⅞	3	5¼	3	7¾	4	0½	4	5⅜	4	10¼
62	1	7¾	1	10¼	2	0⅝	2	3⅛	2	5⅝	2	8	2	10½	3	1	3	3½	3	6	3	8½	4	1⅜	4	6¼	4	11¼
63	1	8	1	10½	2	1	2	3½	2	6	2	8⅝	2	11	3	1⅝	3	4⅛	3	6⅝	3	9⅛	4	2⅛	4	7⅛	5	0⅛
64	1	8⅜	1	10⅞	2	1½	2	4	2	6½	2	9⅛	2	11⅝	3	2¼	3	4¾	3	7¼	3	9⅞	4	3	4	8	5	1⅛
65	1	8⅝	1	11¼	2	1⅞	2	4½	2	7	2	9⅝	3	0¼	3	2⅞	3	5⅜	3	8	3	10½	4	3¾	4	8⅞	5	2
66	1	9	1	11⅝	2	2¼	2	4⅞	2	7½	2	10⅛	3	0⅞	3	3⅜	3	6	3	8⅝	3	11¼	4	4½	4	9¾	5	3
67	1	9⅜	2	0	2	2⅝	2	5¼	2	8	2	10⅝	3	1⅜	3	4	3	6½	3	9⅜	4	0	4	5⅜	4	10⅝	5	4
68	1	9⅝	2	0⅜	2	3	2	5¾	2	8½	2	11⅛	3	1¾	3	4⅝	3	7¼	3	10	4	0¾	4	6⅛	4	11½	5	5
69	1	9⅞	2	0¾	2	3½	2	6¼	2	3⅞	2	11¾	3	2⅜	3	5⅛	3	7⅞	3	10⅝	4	1½	4	7	5	0⅜	5	6
70	1	10¼	2	1	2	3⅞	2	6⅝	2	9⅜	3	0¼	3	3	3	5¾	3	8½	3	11⅜	4	2⅛	4	7¾	5	1¼	5	6⅞
71	1	10⅝	2	1½	2	4¼	2	7	2	9⅞	3	0¾	3	3½	3	6⅜	3	9¼	4	0	4	2⅞	4	8½	5	2⅛	5	7¾
72	1	10⅞	2	1¾	2	4⅝	2	7½	2	10⅜	3	1¼	3	4⅛	3	6¾	3	9⅞	4	0¾	4	3½	4	9¼	5	3	5	8¾
73	1	11¼	2	2⅛	2	5	2	8	2	10⅞	3	1¾	3	4⅝	3	7½	3	10½	4	1⅜	4	4¼	4	10	5	3⅞	5	9¾
74	1	11½	2	2½	2	5½	2	8⅜	2	11⅜	3	2¼	3	5¼	3	7⅞	3	11⅛	4	2	4	5	4	10⅞	5	4¾	5	10⅝
75	1	11⅞	2	2⅞	2	5⅞	2	8⅞	2	11⅞	3	2¾	3	5¾	3	8¾	3	11¾	4	2¾	4	5¾	4	11¾	5	5⅝	5	11⅝
76	2	0⅛	2	3¼	2	6¼	2	9¼	3	0¼	3	3¼	3	6⅜	3	9⅜	4	0⅜	4	3½	4	6½	5	0½	5	6½	6	0½
77	2	0½	2	3½	2	6⅝	2	9¾	3	0¾	3	3⅞	3	6⅞	3	9⅞	4	1	4	4	4	7⅛	5	1¼	5	7⅜	6	1½
78	2	0⅞	2	3⅞	2	7	2	10⅛	3	1½	3	4⅜	3	7½	3	10½	4	1⅝	4	4¾	4	7⅞	5	2	5	8¼	6	2½
79	2	1⅛	2	4⅛	2	7⅜	2	10½	3	1¾	3	4⅞	3	8	3	11⅛	4	2¼	4	5½	4	8½	5	2⅞	5	9⅛	6	3½

Table of the Diameters of Wheels—continued.

Number of teeth.	Pitch of the teeth in inches.													
	1 inch	1⅛	1¼	1⅜	1½	1⅝	1¾	1⅞	2 inch	2⅛	2¼	2½	2¾	3 inch
	Diameter at the pitch circle in feet and inches.													
80	2 1½	2 4⅝	2 7¾	2 11	3 2¼	3 5⅜	3 8½	3 11¾	4 3	4 6⅛	4 9¼	5 3⅝	5 10	6 4⅜
81	2 1¾	2 5	2 8¼	2 11½	3 2⅝	3 5⅞	3 9⅛	4 0⅜	4 3⅛	4 6⅞	4 10	5 4½	5 10⅞	6 5⅜
82	2 2⅛	2 5⅜	2 8⅝	2 11⅞	3 3⅛	3 6⅜	3 9⅝	4 0⅞	4 4¼	4 7½	4 10¾	5 5¼	5 11¾	6 6⅜
83	2 2½	2 5¾	2 9	3 0⅜	3 3⅝	3 6⅞	3 10¼	4 1½	4 4⅞	4 8⅛	4 11½	5 6	6 0⅝	6 7¼
84	2 2¾	2 6	2 9⅜	3 0¾	3 4	3 7½	3 10¾	4 2⅛	4 5½	4 8⅞	5 0⅛	5 6⅞	6 1½	6 8⅛
85	2 3	2 6⅜	2 9¾	3 1¼	3 4½	3 7⅞	3 11¼	4 2¾	4 6⅛	4 9½	5 0⅞	5 7⅝	6 2⅜	6 9⅛
86	2 3⅜	2 6¾	2 10¼	3 1⅝	3 5¼	3 8½	3 11⅞	4 3¼	4 6¾	4 10⅛	5 1⅝	5 8½	6 3¼	6 10½
87	2 3⅝	2 7⅛	2 10⅝	3 2	3 5½	3 9	4 0½	4 3⅞	4 7⅜	4 10⅞	5 2¼	5 9¼	6 4⅛	6 11
88	2 4	2 7½	2 11	3 2½	3 6	3 9½	4 1	4 4½	4 8	4 11½	5 3	5 10	6 5	7 0
89	2 4⅜	2 7⅞	2 11⅜	3 2⅞	3 6½	3 10	4 1½	4 5⅛	4 8⅝	5 0¼	5 3¼	5 10¾	6 5⅞	7 1
90	2 4⅝	2 8¼	2 11¾	3 3¼	3 7	3 10½	4 2⅛	4 5¾	4 9¼	5 0⅞	5 4¼	5 11⅝	6 6¾	7 2
91	2 4⅞	2 8½	3 0¼	3 3⅞	3 7½	3 11	4 2¾	4 6¼	4 9⅞	5 1½	5 5⅛	6 0⅜	6 7⅝	7 2⅞
92	2 5¼	2 8⅞	3 0⅝	3 4¼	3 7⅞	3 11⅝	4 3¼	4 7	4 10½	5 2⅛	5 5⅞	6 1	6 8½	7 3⅞
93	2 5⅝	2 9¼	3 1	3 4¾	3 8⅜	4 0⅛	4 3⅞	4 7½	4 11¼	5 2⅞	5 6⅝	6 2	6 9⅜	7 4⅞
94	2 5⅞	2 9⅝	3 1⅜	3 5⅛	3 8⅞	4 0⅝	4 4⅜	4 8⅛	4 11¾	5 3½	5 7⅜	6 2¾	6 10¼	7 5¾
95	2 6¼	2 10	3 1¾	3 5½	3 9⅜	4 1⅛	4 4⅞	4 8¾	5 0½	5 4¼	5 8	6 3½	6 11⅛	7 6¾

FRICTION.

Friction is an effect produced by bodies rubbing one upon another, which acts as a retarding influence in the motion of all mechanical contrivances, but might not unfrequently be considerably diminished by a due regard to its laws, and a proper attention to the selection of those materials on which a uniform smooth surface may be attained, and which, according to experiments, are least liable to tear or become hot, and cause a roughness to arise when in working contact.

Several doubts existed a few years since respecting the laws of friction; but those doubts were entirely removed through the experiments of Mr. G. Rennie, on his own account, and those of M. Morin, acting for and under the sanction of the French Government, from or by which the following laws have been fully established.

1. That when no unguent is interposed, the friction of any two surfaces (whether of quiescence or of motion) is directly proportional to the force with which they are pressed perpendicularly together; so that for any two given surfaces of contact, there is a constant ratio of the friction to the perpendicular pressure; that is, a double pressure will produce a double amount of friction, a triple pressure a triple amount, &c., of any other proportionate increase of the load.

2. That when no unguent is interposed, the amount of the friction is in every case wholly independent of the extent of the surfaces in contact; so that the force

with which two surfaces are pressed together being the same, their friction is the same, whatever may be the extent of their surfaces of contact.

3. That the friction of motion is wholly independent of the velocity of the motion; that is, supposing two shafts or axles of equal bearings and of equal weights or pressures, but the one making 100 revolutions while the other makes but 50, the amount of friction in each is alike.

4. That when unguents are interposed, the amount of friction depends more upon the nature of the unguent than upon that of the surfaces of contact; and hence, that the nature of the unguent to be applied must be governed by the pressure or insistent weight. Mr. Rennie found, that with the unguents tallow and anti-attrition, on axles under a pressure of from 1 to 5 cwt., the friction did not exceed $\frac{1}{30}$th of the whole pressure; but when softer unguents were applied, as oil, hog's-lard, &c., the ratio of the friction to the pressure considerably increased; from which it is naturally inferred that the consistence of an unguen' ought just to prevent the bodies coming into contac with each other.

5. That the friction of metals, without a stratum unguent interposed, varies as their hardness, the ha metals producing less friction than the soft ones.

6. That without unguents, and within the limits 32½ lbs. pressure per square inch, the friction of h metals upon hard metals may very generally be e mated at about $\frac{1}{6}$th of the whole pressure.

7. That within the limits of their abrasion, the tion of metals is nearly alike; but from 1·66 cwt square inch to 6 cwt. per square inch, the resis increases in a very considerable ratio, being greatest with steel on cast iron, and the least brass on wrought iron.

PRACTICAL PROPERTIES OF WATER AND AIR;

OR OF LIQUIDS AND FLUIDS IN GENERAL.

WATER is the most abundant liquid we possess, and air is the most abundant fluid,—their properties contributing largely to the subserviency of man, not only as the support of his existence, and the comforts of his domestic enjoyments, but because of inherent energies which render them exceedingly advantageous, both as an efficient and disposable source of motive power.

By analysis it is ascertained that water is composed of the gases *oxygen* and *hydrogen* in a state of chemical union; its distinguishing properties, like that of other liquids, being incompressibility,* gravity, capability of flowing, and constant tendency to press outwards in every direction; also that of being easily changed by the absorption of caloric to an aëriform state of any required density or degree of elastic force: hence the principle of the *hydraulic press*, the *water-wheel*, the *steam engine*, &c.

Atmospheric air, like water, is also a gaseous compound: of 100 parts of air, reckoning by weight, 75·55 parts are nitrogen, 23·32 oxygen, and 1·13 carbonic acid and watery vapour; and in such proportions

* Exact experiments have determined that water is not entirely incompressible, but the degree of compressibility is so small, being only about 46¼ millionth parts per atmosphere, that the terms incompressible and non-elastic fluid are not at all in practice inappropriate.

it is most conducive to animal existence. It also in this state possesses many important mechanical properties, a few of which are the following; viz., gravity, fluidity, compressibility, force or pressure, and elasticity; also expansibility by rarefaction or heat; and it is because of the oxygen it contains that combustion is supported. By change of temperature in the atmosphere, currents and winds are created; hence the means by which vessels are enabled to make distant voyages; also the cause which produces circular motion through the medium of the sails of a wind-mill: and it may likewise be observed, that without the pressure of the atmosphere the common pump would be without effect. Such preliminaries, being properly considered, tend much to pave the way to an efficient knowledge of those elements, *water* and *air*, either as regards the production of or retarding mechanical effects in their application as motive power.

1. *Effects produced by water in its natural state.*

Because of liquids possessing the properties of gravity and capability of flowing freely in every direction, sides of vessels, flood-gates, sluices, &c., sustain a pressure equal to the product of the area multiplied by half the depth of the fluid, and by its gravity, in equal terms of unity.

But when a sluice or opening through which a liquid may issue is under any given continued head, the pressure is equal the product of the area multiplied into the height from the centre of the opening to the surface of the fluid.

Ex. 1. Required the pressure of water on the sides of a rectangular cistern 18 feet in length, 13 in width, and 9 in depth.

The terms of measurement or unity are in feet: 1 cubic foot of water = 62·5 lbs.; hence $\overline{18 \times 9 \times 2} + \overline{13 \times 9 \times 2} = 558 \times 4{\cdot}5 \times 62{\cdot}5 = 156937{\cdot}5$ lbs.

Weight of water on bottom $= 18 \times 13 \times 9 \times 62{\cdot}5 = 131625$ lbs.

Ex. 2. Required the pressure on a sluice 3 feet square, and its centre 30 feet from the surface of the water.

$$3 \times 3 \times 30 \times 62{\cdot}5 = 16875 \text{ lbs. pressure.}$$

The weight of water or other fluid is as the quantity, but the pressure exerted is as the vertical height; hence, as fluids press equally in every direction, any vessel containing a fluid sustains a pressure equal to as many times the weight of the column of greatest height of that fluid, as the area of the vessel is to the sectional area of the column.

Ex. Let a cubical vessel whose sides are each 4 square feet have a tube inserted 1 inch in diameter and 6 feet in height, and let both vessel and tube be filled with water; required the whole weight of the water therein contained, and also the whole pressure exerted in tending to burst the vessel.

Cubic contents of the vessel = 8 feet, and each foot = 62·5 lbs. (see page 55).

Then, $62{\cdot}5 \times 8 = 500$. Area of pipe's section = ·7854 inches and height 72 in., also a cubic inch of water = ·03617 lbs.; hence $\cdot7854 \times 72 \times \cdot03617 = 2$ lbs. $+ 500 = 502$ lbs. total weight of the water.

Again, the whole height of the column = 96 inches; then $\cdot7854 \times 96 \times \cdot03617 = 2{\cdot}33$ lbs. pressure of column on an equal area. 144 square inches = 1 square foot, and $\dfrac{144 \times 4 \times 6 \text{ sides}}{\cdot7854} = 4400{\cdot}4$ times the area of the pipe's diameter in the whole surface; therefore $4400{\cdot}4 \times 2{\cdot}33 = 10253$ lbs., or total amount of pressure exerted.

Upon the preceding principles of water rests utility of the hydraulic press. Thus, into a unif cylinder of suitable strength is fitted a piston or moveable in a parallel direction, around which are perly fitted leather collars, to prevent any possibi of the water's escape; the water being injected means of a force-pump, and, by its non-compressi property, repelling the ram with a force equal to number of times the end of the ram exceeds the of the pump.

Ex. Required the repulsive force of a 6-inch r when a power of 50 lbs. is applied to the end of lever, which is as 12 to 1 in effect, and the diam of the pump or plunger $\frac{7}{8}$ths of an inch.

$$\frac{\text{Area of ram} = 28{\cdot}2744}{\text{Area of pump} = {\cdot}6013} = 47;$$

and $50 \times 12 \times 47 = 28200$ lbs., or 12 tons nearly.

When a body is partly or wholly immersed in w or other fluid, the vertical pressure of the fluid te to raise the body with a force equal to the weigh the fluid displaced; hence the weight of any placed quantity of a fluid by a buoyant body eq the weight of that body.

Ex. 1. Suppose a vessel with all its masts, sto and general equipments is found to displace 35, cubic feet of sea water, what is the whole weigh the vessel?

Sea water average 64 lbs. per cubic foot.

$$\frac{35000 \times 64}{2240} = 1000 \text{ tons.}$$

Ex. 2. What must be the thickness of sheet i whereby to form a rectangular vessel 5 feet in len 2 in width, and $1\frac{1}{4}$ in depth, that will just sin

ıches in common water; laps, seams, and rivets not eing taken into account?

5 ft. or 60 in. × 15 = 900 × 2 =	1800	in. or sum of the	sides.
„ 60 „ × 15 =	1440	„	bottom.
2 „ 24 „ × 15 = 360 × 2 =	720	„	ends.
Total	3960		

And 3960 × ·281 (see page 30) = 1112·7, the divisor.

Then 60 in. × 15 × 3 × ·03617 = 156·254 lbs. of water to displace.

Hence $\frac{156{\cdot}254}{1112{\cdot}7} = {\cdot}14$ in., the thickness of iron required.

The resistance by which a moving body is opposed ı passing through water is as the square of the body's elocity; hence, if a body be propelled at a certain elocity by a known power, to double that velocity ʼill require four times the power; to triple it, nine ʼmes the power, &c.

Water in flowing through an orifice or aperture ıder any given head, is governed by the same law gravity as that of a solid body in vacuo descending ·ough the same space, or falling from an equal ght; but as friction is created by the motion of ı hard bodies in contact, so is friction also created the action of the water in passing through the ce or aperture: hence an aperture twice the width ıother will discharge more than a double quantity, use of the area advancing in a much greater ratio at of the resistance. Thus, suppose an opening square feet be required: in a circular form its ·ter would be about 2 feet 3 inches, and its cir·rence, or cause of friction, 7 feet; in a square 2 feet by 2 feet, and the amount of its sides ; but in a rectangular form, 4 feet in length in breadth, the cause of resistance is increased

to 10 feet; thus showing that the circular form is that which ought to be adopted in preference to any other for the conduction of water where practicability will admit.

When water issues out of a circular orifice in a thin plate at the bottom or side of a reservoir, the issuing stream tends to converge to a point at the distance of about half its diameter outside the orifice, and this contraction of the stream reduces the area of its section from 1 to ·619, or nearly $\frac{5}{8}$ths. If a short parallel tube be attached, the vein of the stream is less contracted, and the area will equal ·762. But if the tube attached be the frustum of a cone whose greater end is the aperture, the length equal half the diameter of the aperture, and the area of the small end to the area of the larger as 1 to 1·6, there will be no contraction of the vein: hence the propriety of making the pipe in this form from a reservoir or other head of water through which the greatest quantity, according to its area, is required to pass.

To find the velocity of water issuing through a circular orifice at any given depth from the surface.

Rule.—Multiply the square root of the height or depth to the centre of the orifice by 8·1, and the product is the velocity of the issuing fluid in feet per second.

Ex. Required the velocity of water issuing through an orifice under a head of 11 feet from the surface.

$\sqrt{11} = 3{\cdot}3166 \times 8{\cdot}1 = 26{\cdot}864$ feet, velocity per second.

In the discharge of water by a rectangular aperture in the side of a reservoir, and extending to the surface, the velocity varies nearly as the square root of the height, and the quantity discharged per second equal

⅔rds of the velocity due to the mean height, allowing for the contraction of the fluid according to the form of the opening, which renders the co-efficient in this case equal to 5·1; whence the following general rules.

1. *When the aperture extends to the surface of the fluid.* Multiply the area of the opening in feet by the square root of its depth also in feet, and that product by 5·1; then will ⅔rds of the last product equal the quantity discharged in cubic feet per second.

2. *When the aperture is under a given head.* Multiply the area of the aperture in feet by the square root of the depth also in feet, and by 5·1; the product is the quantity discharged in cubic feet per second.

Ex. 1. Required the quantity of water in cubic feet per second discharged through an opening in the side of a dam or weir, the width or length of the opening being 6½ feet, and depth 9 inches, or ·75 of a foot.

Square root of $\cdot 75 = \cdot 866$.

Then $\dfrac{6\cdot 5 \times \cdot 75 \times \cdot 866 \times 5\cdot 1 \times 2}{3} = 14\cdot 3839$ cubic feet.

Ex. 2. What would be the quantity discharged through the above opening if under a head of water 4 feet in height?

Square root of $4 = 2$, and $2 \times 5\cdot 1 = 10\cdot 2$ feet velocity of the water per second.

And $6\cdot 5 \times \cdot 75 \times 2 \times 5\cdot 1 = 49\cdot 725$ cubic feet discharged in the same time.

PRACTICAL RULES BY WHICH TO DETERMINE THE NECESSARY HEAD, AND QUANTITY OF WATER DISCHARGED THROUGH CIRCULAR PIPES IN A GIVEN TIME.

Rule 1.—To the product of the pipe's length in feet, multiplied by the square of the quantity required in cubic feet per second, add the product of 50 times the pipe's diameter in feet, multiplied into the square of the required quantity per second; divide the sum by the product of 1542·133 into the fifth power of the diameter, and the quotient equal the *head* in feet to produce the velocity required.

Rule 2.—Multiply 1542·133 times the fifth power of the pipe's diameter in feet by the head of water in feet, and divide the product by the sum of the pipe's length and 50 times its diameter; the square root of the quotient equal the *quantity* discharged in cubic feet per second.

Ex. 1. Required the head of water necessary to produce a velocity of 2·988 feet, or 9·387 cubic feet per second, by a pipe of 2 feet in diameter and 180 feet in length.

$$\frac{\overline{9{\cdot}387^2 \times 180} + \overline{50 \times 2 \times 9{\cdot}387^2}}{1542{\cdot}133 \times 2^5} = \frac{15860{\cdot}8}{49348} = {\cdot}5 \text{ of a foot head.}$$

Ex. 2. What quantity of water per second will be discharged through a pipe of 2 feet diameter and 180 feet in length, when pressed by a head of water ·5 of a foot in height.

$$\frac{1542{\cdot}133 \times 2^5 \times {\cdot}5}{180 + \overline{50 \times 2}} = \sqrt{88{\cdot}1219} = 9{\cdot}387 \text{ feet per second.}$$

And the area of the end of the pipe in feet, multiplied into the velocity, equal the quantity in cubic feet.

Note.—The above rules apply strictly only to straight pipes; *bends* in a pipe diminish the velocity of a fluid equal to ·003

times the sum of the sines of the several angles of inflection; hence, a bend in a pipe should not be sudden, and on no account should an angle be admitted.

Table of the Diameters of Pipes through which a required quantity of water may be discharged in a given time.

Cubic feet per minute.	Diameter in inches.	Cubic feet per minute.	Diameter in inches.	Cubic feet per minute.	Diameter in inches.
1	1	25	4¾	160	12⅛
2	1⅜	30	5¼	170	12½
3	1⅝	35	5⅝	180	12¾
4	1⅞	40	6	190	13¼
5	2⅛	45	6½	200	13⅝
6	2⅜	50	6¾	225	14⅜
7	2⅝	55	7⅛	250	15⅛
8	2¾	60	7½	275	16
9	2⅞	65	7¾	300	16⅝
10	3	70	8	350	18
11	3⅛	80	8⅝	400	19¼
12	3¼	90	9⅛	441	20⅛
13	3½	100	9⅝	529	22
14	3⅝	110	10	625	24
15	3¾	120	10½	729	26
16	3⅞	130	11	841	28
18	4	140	11⅜	900	29
20	4¼	150	11¾	1000	30

The combined properties of gravity and fluidity which water possesses render it so available as a source of motive power; *gravity* being the property by which the power is produced, and *fluidity* that by which it is so commodiously qualified to the various modifications in which it is employed.

Water, it is ascertained, is subject to the same laws of gravity as those of solid bodies, and thereby accumulates velocity or effect in an equal ratio when falling through an equal space, or descending from an equal height: hence the velocity attained is as the

square root of the height of its fall; and i
quite satisfactorily decided, that because of t
elastic property of water, its greatest effect is
when acting by gravity throughout its whol
whether it be applied on a water-wheel, tu
other machine, through which circular motio
the immediate result.

In regard to *Water-Wheels* and other M
through which motion is produced by the
water, considerable discrepancy of opinion
existed, both as to form and velocity, besid
essential points requisite in gaining a max
effect with the least possible strain; but thes
are now in a great measure removed thr
periments by the Franklin Institute in
added to those in France by Morin, and th
of a patented machine by Whitelaw and Stirr
land, combined with pertinent observations
marks by interested parties in this as well as
countries: hence have been deduced the
demonstrative conclusions.

1. That to gain a maximum of effect b
zontal water-wheel, the water must be laid
wheel on the stream side, and the diamet
wheel so proportioned to the height of the
the water may be laid on about 52¾ degree
from the summit of the wheel; or the heig
fall being 1, the height or diameter of t
equal 1·108.

2. That the periphery of a water-wheel
move at a velocity equal to about twice th
root of the fall of the water in feet per sec
the number of buckets equal 2·1 times th
diameter in feet; also, that precautionary
adopted for the escape of the air out of the

either by making the stream of water a few inches narrower than the wheel, or otherwise.

3. That because of water producing a less efficient power by impulse than gravity, turbines, or machines through which the motion is obtained by reaction, are greatly preferable to undershot, or low breast wheels.

4. That a head* of water is required sufficient to cause the velocity of its flowing to be as 3 to 2 of the wheel; $\frac{1}{9}$th of the wheel's diameter being an approximate height, near enough for practical purposes.

5. That the effective power of a wheel constructed according to these restrictions is equal to the product of the number of cubic feet, and velocity in feet per minute, multiplied into ·001325.

Example for general illustration.

Suppose a fall of water 25 feet in height, over which is delivered 112 cubic feet per minute; required the various peculiar requisites for a wheel to be in accordance with the preceding rules.

1st. $25 \times 1{\cdot}08 = 27$ feet, the wheel's diameter.

2nd. $\sqrt{25} \times 2 = 10$ feet, velocity of the wheel in feet per second. Also $27 \times 2{\cdot}1 = 56{\cdot}7$, say 57 buckets.

3rd. $27 \div 9 = 3$ feet, head of water required.

4th. $112 \times 10 \times 60 \times {\cdot}001325 = 89$ horses' power.

The *turbine* of Fourneyron, in France, and the patented *Water-Mill* of Whitelaw and Stirrat, Scotland, have of late years attracted a considerable share of public attention, their simplicity of construction and asserted effects in like situations being equal to those of the best applied water-wheels. In their manner of construction they differ, but in principle they are the same; the action of each being created by a centrifugal and tangential force, caused by the weight or impulsion of a column

* By head is meant the distance from the surface of the water to that point at which it strikes upon the wheel.

of water whose height or altitude is equal to twi the height of the fall due to the water's velocit and in order to produce a maximum of effect either the one or the other by the pressure a centrifugal force of the effluent water, it is nece sary that the emitting tubes, or helical channels the machine, be so curved that the apertures shall in a right line with the radius of the wheel.

In 1838 a number of experiments were made France by Morin, with a view to the more gener introduction of turbines, and a positive proof of th merited qualities in preference to wheels of impul which terminated considerably in favour of turbin and from which the following deductions were mad

1. That turbines are equally adapted to great as small falls of water.

2. That they are capable of transmitting a usef effect to from 70 to 78 per cent. of the absolute powe

3. That their velocities may vary very considerab from the maximum effect, without differing very se sibly from it.

4. That they will work nearly as effectually wh drowned to the depth of 5 or 6 feet as when free, a consequently, they will make use of the whole of t fall when placed below the level of extreme low wate

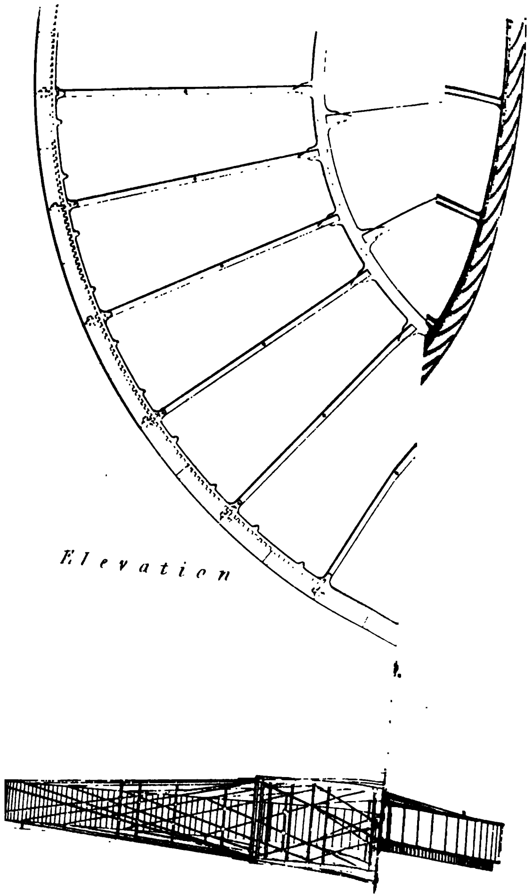
5. That they may receive variable quantities water without altering the ratio of the power to t effect. Corresponding results have also been realiz by Whitelaw and Stirrat's machine: hence what said of the one is equally applicable to the other.

General Rule by Mr. Whitelaw, whereby to compu the power of their Turbine, or Water-Mill.

Rule.—Multiply the effective quantity of wat flowing in cubic feet per minute by the height of t *fall* of the water in feet, and divide the product by 70

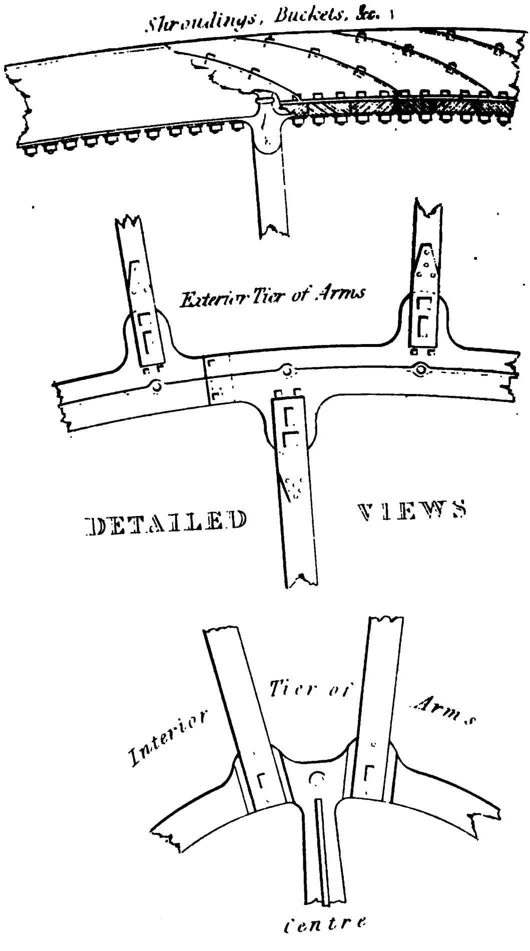
AN OVRSHOT WATER WHEEL, C ... ONDO

Pla



J.W.Lowry fc.

Published by John Weale 59 High Holborn.



John Weale, 59, High Holborn, 1858.

e quotient equal the effect produced in horses' wer.

Ex. Required the power produced by 1400 cubic et per minute over a fall of 30 feet.

$$\frac{1400 \times 30}{700} = 60 \text{ horses' power.}$$

Plates G and H exhibit miniature views of a ponrous overshot water-wheel, chiefly of wrought iron, id in which novelty of construction, immense diaeter, and great efficiency, have rendered it an object universal interest throughout the district in which is situated: its nominal power is that of 30 horses, it upwards of 40 of indicated resistance seems not aterially to diminish its velocity; and no doubt, on count of the improved form of the buckets, the eatest amount of the water's effect is obtained.

2. *Effects produced by water in an aëriform state.*

When water in a vessel is subjected to the action fire, it readily imbibes the heat or fluid principle of hich the fire is the immediate cause, and sooner or ter, according to the intensity of the heat, attains a mperature of 212° Fahrenheit. If at this point of mperature the water be not enclosed, but exposed atmospheric pressure, ebullition will take place, nd steam or vapour will ascend through the water, arrying with it the superabundant heat, or that hich the water cannot under such circumstances of ressure absorb, to be retained and to indicate a higher mperature.

Water, in attaining the aëriform state, is thus unirmly confined to the same laws under every degree f pressure; but as the pressure is augmented, so is he indicated temperature proportionately elevated: ence the various densities of steam, and correspondng degrees of elastic force.

Table of the Elastic Force of Steam, and corresponding Temperature of the Water with which it is in contact.

Pressure per square inch, atmospheric pressure included.		Elastic Force in		Temperature in Degrees of			Volume of Steam compared with vol. of Water.
		Inches of Mercury.	Metres of Mercury.	Fahr.	Reaum.	Cent.	
lbs.	kilog.						
14·7	6·668	30·00	·762	212·0	80·0	100·0	1711
15	6·80	30·60	·778	212·8	80·4	100·4	1670
16	7·26	32·64	·829	216·3	81·9	102·4	1573
17	7·71	34·68	·880	219·6	83·3	104·2	1488
18	8·16	36·72	·932	222·7	84·7	105·9	1411
19	8·62	38·76	·984	225·6	86·0	107·6	1343
20	9·07	40·80	1·037	228·5	87·3	109·2	1281
21	9·52	42·84	1·089	231·2	88·5	110·7	1225
22	9·98	44·88	1·140	233·8	89·7	112·1	1174
23	10·43	46·92	1·192	236·3	90·8	113·5	1127
24	10·88	48·96	1·244	238·7	91·9	114·8	1084
25	11·34	51·00	1·296	241·0	93·0	116·1	1044
26	11·79	53·04	1·348	243·3	93·9	117·4	1007
27	12·25	55·08	1·400	245·5	94·9	118·6	973
28	12·70	57·12	1·452	247·6	95·8	119·8	941
29	13·15	59·16	1·503	249·6	96·7	120·9	911
30	13·61	61·21	1·555	251·6	97·6	122·0	883
31	14·06	63·24	1·607	253·6	98·5	123·1	857
32	14·51	65·28	1·659	255·5	99·3	124·2	833
33	14·97	67·32	1·711	257·3	100·1	125·2	810
34	15·42	69·36	1·763	259·1	100·9	126·2	788
35	15·87	71·40	1·814	260·9	101·7	127·2	767
36	16·33	73·44	1·866	262·6	102·5	128·1	748
37	16·78	75·48	1·918	264·3	103·2	129·1	729
38	17·23	77·52	1·970	265·9	104·0	129·9	712
39	17·69	79·56	2·022	267·5	104·7	130·8	695
40	18·14	81·60	2·074	269·1	105·4	131·7	679
41	18·59	83·64	2·126	270·6	106·0	132·6	664
42	19·05	85·68	2·178	272·1	106·7	133·4	649
43	19·50	87·72	2·229	273·6	107·4	134·2	635
44	19·96	89·76	2·281	275·0	108·0	135·0	622
45	20·41	91·80	2·333	276·4	108·6	135·8	610
46	20·86	93·84	2·385	277·8	109·2	136·6	598
47	21·32	95·88	2·437	279·2	109·9	137·3	586
48	21·77	97·92	2·489	280·5	110·4	138·1	575
49	22·22	99·96	2·541	281·9	111·1	138·8	564
50	22·68	102·00	2·592	283·2	111·6	139·6	554

The preceding Table is peculiarly adapted for estimating the power of steam engines on the condensing principle, because in such the effective force of the steam is the difference between the total force and the resisting vapour retained in the condenser. The following Table is more adapted for estimating the effects of non-condensing engines, as, in such, the atmospheric pressure is not generally taken into account, engines of this principle being supposed to work in a medium; or, the atmospheric pressure on the boiler, to cause a greater density of steam, is equal to the resisting atmosphere which the effluent steam has to contend with on leaving the cylinder.

Table of the Elastic Force of Steam, the Pressure of the Atmosphere not being included.

Elastic Force in			Temperature in degrees of Fahr.	Volume of Steam Water being 1.	Cubic in. of Water in a cubic foot of Steam.
Atmosphere.	lbs. ℔ sq. in.	in. of Merc.			
1·19	2·5	5·15	220	1496	1·14
1·22	3	6·18	222	1453	1·18
1·29	4	8·24	225	1366	1·25
1·36	5	10·3	228	1282	1·33
1·70	10	20·6	240	1044	1·64
2·04	15	30·9	251	883	1·93
2·38	20	41·2	260	767	2·23
2·72	25	51·5	268	678	2·52
3·06	30	61·8	275	609	2·81
3·40	35	72·1	282	553	3·09
3·74	40	82·4	288	506	3·38
4·08	45	92·7	294	468	3·66
4·42	50	103·0	299	435	3·93
4·76	55	113·3	304	407	4·20
5·10	60	123·6	309	382	4·48

Steam, independent of the heat indicated by an mmersed thermometer, also contains heat that cannot

be measured by any instrument at present known, and, in consequence of which, is termed latent or concealed heat; the only positive proof we have of its existence being that of incontestable results or effects produced on various bodies. Thus, if one part by weight of steam at 212°, be mixed with nine parts of water at 62°, the result is water at 178·6°; therefore, each of the nine parts of water has received from the steam 116·6° of heat, and consequently the steam has diffused or given out $116{\cdot}6 \times 9 = 1049{\cdot}4 - 33{\cdot}4 = 1016°$ of heat which it must have contained. Again, it is ascertained by experiment, that if one gallon of water be transformed into steam at 212°, and that steam allowed to mix with water at 52°, the whole will be raised to the boiling point, or 212°. From these and other experiments, it is ascertained that the latent heat in steam varies from 940° to 1044°, the ratio of accumulation advancing from 212°, as the steam becomes more dense and of greater elastic force: hence the severity of a scald by steam to that by boiling water.

It is because of the latent heat in steam, or water in an aëriform state, that it becomes of such essential service in *heating*, *boiling*, *drying*, &c. In the heating of buildings, its *economy*, *efficiency*, and *simplicity* of *application*, are alike acknowledged;—the steam being simply conducted through all the departments by pipes, by extent of circulation condenses, the latent heat being thus given to the pipes and diffused by radiation. In boiling, its efficiency is considerably increased if advantage be taken of sufficiently enclosing the fluid and reducing the pressure on its surface by means of an air-pump; thus, water in a vacuum boils at about a temperature of 98°, and in sugar-refining, where such means are employed, the syrup is boiled at 150°.

Steam is also of great utility as a productive source of motive power; and in this respect its properties are, *elastic force*, *expansive force*, and *reduction by condensation*. Elastic force signifies the whole urgency or power the steam is capable of exerting with undiminished effect. By expansive force is generally understood the amount of diminishing effect of the steam on the piston of a steam engine, reckoning from that point of the stroke where the steam of uniform elastic force is cut off; but it is more properly the force which steam is capable of exerting when expanded to a known number of times its original bulk. And

Condensation, here understood, is the abstraction or reduction of heat by another body, and consequently not properly a contained property of the steam, but an effect produced by combined agency, in which steam is the principal; because any colder body will extract the heat and produce condensation, but steam cannot be so beneficially replaced by any other fluid capable of maintaining equal results.

The rules formed by experimenters as corresponding with the results of their experiments on the elastic force of steam at given temperatures vary, but approximate so closely that the following rule, because of being simple, may in practice be taken in preference to any other.

Rule.—To the temperature of the steam in degrees of Fahrenheit, add 100, divide the sum by 177, and the 6th power of the quotient equal the force in inches of mercury.

Ex. Required the force of steam corresponding to a temperature of 312°.

$$\frac{312+100}{177}=2{\cdot}3277^6=159 \text{ inches of mercury.}$$

But the Table, page 242, is much better adapted to practical purposes, as the various results or effects are obtained simply by inspection.

To estimate the amount of advantage gained by using steam expansively in a steam engine.

When steam of a uniform elastic force is employed throughout the whole ascent or descent of the piston, the amount of effect produced is as the quantity of steam expended. But let the steam be shut off at any portion of the stroke, say, for instance, at one-half, it expands by degrees until the termination of the stroke, and then exerts half its original force; hence an accumulation of effect in proportion to the quantity of steam.

Rule.—Divide the length of the stroke by the distance or space into which the dense steam is admitted, and find the hyperbolic logarithm of the quotient, to which add 1, and the sum is the ratio of the gain.

Ex. Suppose an engine with a stroke of 6 feet, and the steam cut off when the piston has moved through 2; required the ratio of gain by uniform and expansive force.

$6 \div 2 = 3$; hyperbolic logarithm of $3 = 1{\cdot}0986 + 1 = 2{\cdot}0986$ ratio of effect; that is, supposing the whole effect of the steam to be 3, the effect by the steam being cut off at $\frac{1}{3} = 2{\cdot}0986$.

Again, let the greatest elastic force of steam in the cylinder of an engine equal 48 lbs. per square inch, and let it be cut off from entering the cylinder when the piston has moved $4\frac{1}{2}$ inches, the whole stroke being 18; required an equivalent force of the steam throughout the whole stroke.

$18 \div 4{\cdot}5 = 4$, and $48 \div 4 = 12$.
Logarithm of $4 + 1 = 2{\cdot}38629$.
Then $2{\cdot}38629 \times 12 = 28{\cdot}635$ lbs. per square inch.

Table of Hyperbolic Logarithms.

No.	Logarithm.	No.	Logarithm.	No.	Logarithm.	No.	Logarithm.
1¼	·22314	3½	1·25276	5¾	1·74919	8	2·07944
1½	·40546	3¾	1·32175	6	1·79175	8½	2·14006
1¾	·55961	4	1·38629	6¼	1·83258	9	2·19722
2	·69314	4¼	1·44691	6½	1·87180	9½	2·25129
2¼	·81093	4½	1·50507	6¾	1·90954	10	2·30258
2½	·91629	4¾	1·55814	7	1·94591	12	2·48490
2¾	1·01160	5	1·60943	7¼	1·98100	14	2·63905
3	1·09861	5¼	1·65822	7½	2·01490	16	2·77258
3¼	1·17865	5½	1·70474	7¾	2·04769	18	2·89037

In regard to the other case of expansion: When the temperature is constant the bulk is inversely as the pressure: thus, Suppose steam at 30 ℔s. per square inch, required its bulk to that of original bulk, when expanded so as to retain a pressure equal to that of the atmosphere, or 15 ℔s.

$$\frac{15+30}{15} = 3 \text{ times its original bulk.}$$

Condensation of steam for motive purposes, generally, is effected by cold water, the quantity of which may be estimated by the following rule. From 1000 plus the temperature of the steam, subtract the required temperature of the condensed water, divide the remainder by the temperature of the condensed water minus the temperature of the cold or condensing water, and the quotient equal the number of times that the quantity, for condensation, must exceed that by which the steam is formed.

Ex. Required the ratio or quantity of water for condensation to 1 of water for the formation of steam, the temperature of the steam being 220°, and the required temperature of condensed water 180°.

$$\frac{1000+220-180}{180-52} = 8 \text{ times the quantity.}$$

Water holding impurities in solution tends to retard its attaining the aëriform state, and so impairs the amount of its elastic force at an equal temperature, as exhibited in the following Tables. Thus, common water boils at 212° Fahrenheit.

Name of Substance.	Proportionate quantity in 100 parts by weight of water.		Boiling points.
Salts in sea water.	3·03.		213·2° F.
Sulphate of soda	In common water.	31·5	213
Sulphate of iron		64	216
Alum		52	220
Sulphate of lime		45	220
Sulphate of magnesia..		57·5	222
Muriate of soda		30	224
Nitrate of soda		60	246
Acetate of soda		60	256

Elastic Force of Steam in Inches of Mercury.

Common water	boiling point,	212° F.	elastic force 30 in.
Sea water . . .	at	212 „	„ 23·05 „
Common water	boiling point,	216° F.	elastic force 32·5 in.
Sea water . . .	at	216 „	„ 24·6 „
Common water	boiling point,	220° F.	elastic force 35·1 in.
Sea water . . .	at	200 „	„ 26·5 „

Hence the propriety of procuring, for steam, water in its purest state.

3. *Effects produced by air in its natural and also in a rarefied state.*

The weight or pressure of the atmosphere is equal to the weight of a column of water 34 feet in height, or to a column of mercury 30 inches in height, or to 14·7 ℔s. av. per square inch at a mean temperature. But air, like all other gases, is rendered lighter by

the application of heat, for then the particles of the mass are repelled from each other, or rarefied, and occupy a greater space. Rarefied air being specifically lightest, mounts above that of common density; hence change of temperature, and the principal cause of winds.

Table of the Expansion of Atmospheric Air by Heat.

Deg. of Fahr.	Bulk.	Deg. of Fahr.	Bulk.	Deg. of Fahr.	Bulk.
32°	1000	65°	1077	100°	1152
35	1007	70	1089	120	1194
40	1021	75	1099	140	1235
45	1032	80	1110	160	1275
50	1043	85	1121	180	1315
55	1055	90	1132	200	1364
60	1066	95	1142	212	1376

The pressure or gravity of the atmosphere being equal to a column of water 34 feet in height, is the means or principle on which rests the utility of the common pump, also of the syphon and all other such hydraulic applications. In a pump the internal pressure on the surface of the liquid is removed by the action of the bucket, and as by degrees the density becomes lessened, so the water rises by the external pressure to the above-named height; and at such height it will remain, unless by some derangement of construction taking place, the atmospheric fluid is allowed to enter and displace the liquid column. But observe, if the temperature of the water or other liquid be so elevated that steam or vapour arise through it, then, according to the vapour's accumulation of density, may the action of the pump be partially or wholly destroyed; and the only means of evasion in such cases is to place the working bucket beneath the surface of the liquid which is required to be raised.

Table showing the quantity of Water per lineal foot in Pumps or Vertical Pipes of different diameters.

Diameter of pump in inches.	Number of gallons per lineal ft.	Number of cubic feet per lineal ft.	Diameter of pump in inches.	Number of gallons per lineal ft.	Number of cubic feet per lineal ft.
2	·136	·0218	8	2·176	·3490
2¼	·172	·0276	8¼	2·314	·3712
2½	·212	·0340	8½	2·456	·3940
2¾	·257	·0412	8¾	2·603	·4175
3	·306	·0490	9	2·754	·4417
3¼	·359	·0576	9¼	2·909	·4666
3½	·416	·0668	9½	3·068	·4923
3¾	·478	·0766	9¾	3·232	·5184
4	·544	·0872	10	3·400	·5454
4¼	·614	·0985	10¼	3·572	·5730
4½	·688	·1104	10½	3·748	·6013
4¾	·767	·1230	10¾	3·929	·6302
5	·850	·1363	11	4·114	·6599
5¼	·937	·1503	11¼	4·303	·6902
5½	1·028	·1649	11½	4·496	·7212
5¾	1·124	·1803	11¾	4·694	·7529
6	1·224	·1963	12	4·896	·7853
6¼	1·328	·2130	12½	5·312	·8521
6½	1·436	·2304	13	5·746	·9217
6¾	1·549	·2489	13½	6·196	·9939
7	1·666	·2672	14	6·664	1·0689
7¼	1·787	·2866	15	7·650	1·2271
7½	1·912	·3067	16	8·704	1·3962
7¾	2·042	·3275	18	11·016	1·7670

Examples illustrative of the Utility of the Table.

1. Required the quantity of water lifted by each stroke of the bucket of a 9½-inch pump, the length of the stroke being 2¼ feet.

$3·068 \times 2·25 = 6·903$ gallons each stroke.

2. What length of stroke with a 6-inch pump will be necessary to discharge 44 gallons of water per

minute, the number of strokes being 18 in the given time?

$$\frac{44}{1 \cdot 224 \times 18} = 2 \text{ feet, the length of stroke.}$$

3. What must be the diameter capable of raising 25 cubic feet of water per minute, the length of the stroke being $2\frac{1}{2}$ feet, and making 16 effective strokes per minute?

$$\frac{25}{2 \cdot 5 \times 16} = \cdot 625, \text{ or } 10\tfrac{3}{4} \text{ inches nearly.}$$

It is by the oxygen of the atmosphere that combustion is supported. The common combustibles of nature are chiefly compounds of carbon and hydrogen, which, during combustion, combine with the oxygen of the atmosphere, and are converted into carbonic acid and watery vapour, different species of fuel requiring different quantities of oxygen. The quantity required for the combustion of a pound of coal varies from 2 to 3 lbs., according to the quality of the coal: 60 cubic feet of atmospheric air is necessary to produce 1 lb. of oxygen.

The pressure or fluid properties of the atmosphere oppose bodies in passing through it, the opposing resistance increasing as the square of the velocity of the body, and the resistance per square foot in lbs. as its velocity in feet per second, multiplied into ·002288. Thus, suppose a locomotive engine in a still atmosphere, at a velocity of 25 miles per hour, presents a resisting frontage of 20 feet; required the amount of opposing resistance at that velocity.

25 miles per hour equal 36·67 feet per second.

Then $36 \cdot 67^2 \times \cdot 002288 \times 20 = 61 \cdot 5$ lbs. constant opposing force.

Table of the Force and common Appellations given to Winds at different velocities.

Velocity of the Wind in		Force in lbs. avoirdupois per square foot.	Common Appellations given to the Wind.
Miles per hour.	Feet per second.		
1	1·47	·005	Hardly perceptible.
2	2·93	·020	Just perceptible.
3	4·40	·044	
4	5·87	·079	Gentle pleasant wind.
5	7·33	·123	
10	14·67	·492	Pleasant brisk gale.
15	22·00	1·107	
20	29·34	1·968	Very brisk.
25	36·67	3·075	
30	44·01	4·429	High winds.
35	51·34	6·027	
40	58·68	7·873	Very high.
45	66·01	9·963	
50	73·35	12·300	A storm or tempest.
60	88·02	17·715	A great storm.
80	117·36	31·490	A hurricane.

In order to gain the greatest amount of the wind's impulsive effect to produce rotary or circular motion by the sails of a wind-mill, the total surface of the sails presented to the wind ought to be about ⅞ths of the circle's surface which is formed by their motion, and each sail angled to the plane of motion as follows, the whip or back being divided into six equal parts.

Distance from centre of motion	1	2	3	4	5	6	Smeaton's rule.
Angle with plane of motion ..	18°	19	18	16	12½	7	
By G. Forrester, Liverpool ..	24°	21	18	14	9	3	

RULES, TABLES, &c., RELATIVE TO BOILERS AND THE STEAM ENGINE.

THE Boiler of a Steam Engine may be explained as that portion of the structure in which the vital principle of the engine is generated; consequently its construction is of the utmost importance, for upon the proper efficiency of the boiler depends in a great measure the efficiency of the engine.

Boilers not unfrequently, because of unavoidable peculiarities, are necessarily constructed of various forms; but for land or stationary engine boilers, if no thwarting circumstances intervene, either the waggon or cylindrical forms are commonly resorted to; the former for those of condensing engines, and the latter for those of the high-pressure principle.

In the construction of boilers, much attention ought to be paid in avoiding thin films of water where the action of the fire is great, because it is neither consistent with safety, nor can there be the proper quantities of steam generated according to the surface exposed, unless under some extraordinary degree of pressure. Also convex surfaces, exposed to the action of the steam, unless properly supported, ought strenuously to be avoided. Large water spaces, concave surfaces, or straight plates securely stayed, with ample steam room, are the chief requisites to be attended to.

1. *To determine the proper quantity of heating surface in a boiler for an engine with a cylinder of a given capacity, and steam at any density required.*

Rule.—Multiply 375 times the area of the cylinder in feet by the velocity of the piston in feet per minute, and divide the product by the volume of steam to 1

of water at the density required (see Table, page 242), and the quotient is the amount of effective heating surface in square feet.

Ex. Required the amount of effective heating surface in a boiler for an engine whose cylinder is $4\frac{1}{2}$ square feet in area, and the piston's velocity 224 feet per minute, the pressure of the steam to equal 5 lbs. per square inch above the pressure of the atmosphere.

$\frac{375 \times 4 \cdot 5 \times 224}{1282} = 295$ square feet nearly; the fire-grate being in accordance with the following rule.

Multiply the number of square feet of heating surface by ·12, the product equal the area of fire-grate in square feet, thus:

$295 \times \cdot 12 = 35 \cdot 4$ square feet of furnace-bar.

Note.—By effective heating surface is meant horizontal surfaces over fire, flame, or heated air; vertical or side surfaces requiring about $1\frac{3}{4}$ ft. to equal in effect 1 of horizontal surface.

2. *To determine the proper dimensions for a waggon-shaped boiler, when the amount of effective heating surface in square feet is obtained by the preceding rule.*

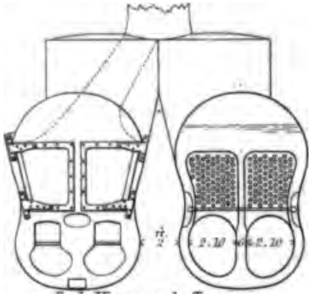
1. The bottom surface equal half the whole surface.
2. The length of the boiler equal twice the square root of bottom surface.
3. The width equal one-fourth the length; and
4. The height equal one-third the length.

Ex. Required the dimensions for a boiler of the waggon form that may present an effective heating surface of 295 square feet.

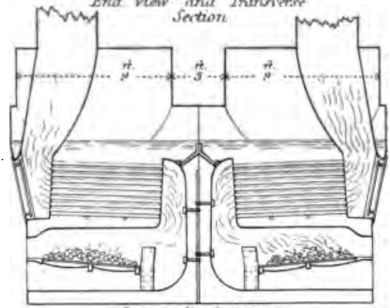
Bottom surface $= 295 \div 2$, or $147 \cdot 5$ square feet.
Length . . . $= \sqrt{147 \cdot 5} \times 2$, or $24 \cdot 26$ feet.
Width . . . $= 24 \cdot 26 \div 4$, or $6 \cdot 06$ feet.
Height . . . $= 24 \cdot 26 \div 3$, or $8 \cdot 08$ feet.

Note.—The amount of side or vertical surface equal twice

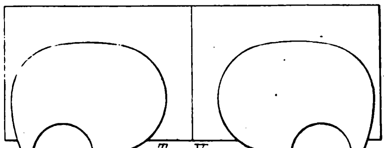
Plate K



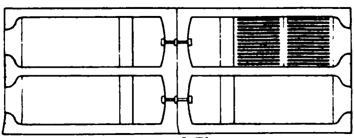
End View and Transverse Section



Longitudinal Section



Top View



Ground Plan

Plans of the Boilers on board the Peninsular Co.s Steam Ship Braganza
By Mess.rs Bury, Curtis and Kennedy, Liverpool.

W. T. del.

London J. Weale 185[illegible]

e length of the boiler, added to the width, and multiplied by 1·75 to obtain that of effective surface; hence,

$$\frac{147{\cdot}5 \times 1{\cdot}75}{24{\cdot}26 \times 2 + 6{\cdot}06} = 4{\cdot}7 \text{ feet, depth of side flue.}$$

3. *To determine the dimensions for a cylindrical oiler.*

Rule.—Extract the square root of 1·34 times the ffective heating surface in square feet, and twice the oot equal the boiler's circumference in feet; also, he circumference equal the length.

Ex. Let a cylindrical boiler be required with an ffective heating surface of 86 square feet; what must e its length and diameter in feet?

$\sqrt{86 \times 1{\cdot}34} = 10{\cdot}74 \times 2 = 21{\cdot}48$ feet circumference, or 6 feet 10 inches diameter, and 21·48 feet in length.

Note.—When an internal flue is to be inserted in a boiler, he external surface of the boiler may be diminished in length, qual to half the exposed surface of the flue. Observe, also, hat the height of the contained water in boilers generally ught to be about ⅔rds the whole height of the boiler.

Marine Engine Boilers have become so varied in heir designs, that any attempt at enumerating—by ver so slight a description—those that may be consilered worthy of record, would much exceed the limits f my present purpose; but having been favoured by Messrs. Bury, Curtis, and Kennedy, with particulars f the boilers constructed by them for the 'Braganza' team vessel, and which have given the highest legree of satisfaction in every respect, I annex lesigns and data, in preference to those of any other lescription. (See Plate K.)

These boilers are constructed so as to work at 0 lbs. per square inch if required; they are four n number; the diameter of each cylinder is 62⅛ nches, length of stroke 5½ feet, or calculated velocity bout 231 feet per minute: the nominal power of each

engine is 140 horses, and the heating surface per horse-power is 14·1 square feet.

Now $14·1 \times 140 = 1974$ square feet to each engine.

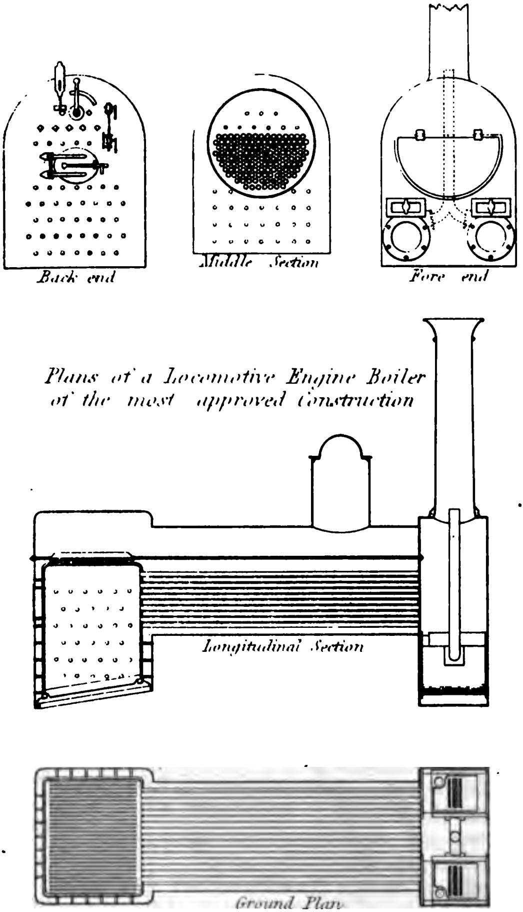
Then as per rule (page 253), 375 multiplied by the area of cylinder or 21 feet, and by the velocity per minute or 231 feet, and divided by 1044 (see Table, page 243) or volume of steam to 1 of water, at 10 lbs. per square inch, equal 1742·4 square feet; to which add about $\frac{1}{8}$th of the quotient, or 217·8, for side or vertical surface, equal 1960·2 square feet to each engine,—thus nearly corresponding with *their* given quantity of heating surface.

Note.—In the four boilers there are 608 brass tubes, $6\frac{1}{4}$ feet in length, and 3 inches in diameter. The length of each fire-place is 5 feet 10 inches, and breadth 2 feet 10; there are ·56 of a square foot of fire-bar to each cubic foot of cylinder capacity, and ·16 of a square foot of tube aperture to each square foot of fire-bar, the openings of the tubes being reduced by the thickness of the tube hoops. The diameter of each chimney, of which there are two, is 3 feet 5 inches.

Locomotive Boilers, in the manner of their construction, are a class which, of necessity, demand the utmost degree of qualified attention, because of the great pressures they are required to sustain, and the unavoidably narrow limits in which such vast volumes of steam are required to be generated.

In boilers of this description, it is of the most essential consequence that the water spaces in the fire-box be of a sufficient width, say, on the back and sides, not less than $2\frac{3}{4}$ to 3 inches, and in the front, where the tendency of the fire is urged by the action of the blast-pipe, at least $3\frac{1}{2}$ inches.

The boiler which I have selected for illustration (see Plate L) is of the most modern description; and from an intimate knowledge of its performances, I am enabled to assert, with full confidence, that it possesses efficient and economical properties to the production of steam.



T., del.

G. Gladwin, sc.

London: J. Weale, 1853.

pecified particulars relative to the Boiler and Engine.

Diameter of cylinders	14 inches.
Length of stroke	18 „
Lap of the valve	1 „
Diameter of driving wheels	5½ feet.
Length of internal fire-box	2 feet 11½ inches.
Width of ditto	3 „ 5 „
Length of cylindrical part of boiler	8 „ 8 „
Diameter of do.	3 „ 4½ „
Length of tubes	8 „ 11½ „
Number of tubes	133, of brass.
Interior diameter of do.	1⅝ inches.
Diameter of blast-pipe	4 „

About 112 lbs. of coke consumed in this boiler vaporate 84 gallons of water; and from 20 to 25 lbs. f coke are consumed per mile.

Heating Powers of Combustible Substances.

Species of combustible.	lbs. of water heated from 32° to 212°.	lbs. of boiling water evaporated by 1 lb. of fuel.	lbs. of atmospheric air to each lb. of fuel.
Wood in its ordinary state	26	4·72	4·47
Wood charcoal	73	13·37	11·46
Coal	60	10·90	9·26
Coke	65	11·81	11·46
Turf	30	5·45	4·60
Turf charcoal	64	11·63	9·86

In regard to the giving of an order for a steam ngine of any required number of horses' power, it as been argued and ultimately decided, that in a ommercial point of view the order is not sufficiently ompleted by the dimensions of cylinder, boiler, &c. eing of ample magnitude to produce the specified ynamical effect in horses' power; and not unless corsponding with the established custom by Boulton nd Watt, or that of other manufacturers of equally ell known respectability: hence, generally, the fol-

lowing Tables may be better adapted to practice than even the most simple rule.

Table of Dimensions for Steam Engine Cylinders by celebrated makers.

Stationary Condensing Engines, by Boulton & Watt.			Marine Engines, by Maudslay, Napier, &c.			High-Pressure, or Non-Condensing Engines, by various makers.				
Nominal horses' power.	Diameter of cylinders in inches.	Lengths of strokes in feet.	Nominal horses' power.	Diameter of cylinders in inches.	Lengths of strokes in feet.	Nominal horses' power.	Diameters of cylinders, the force of the steam being, per square inch, 25 lbs.	30 lbs.	40 lbs.	50 lbs.
6	14½	3	10	20	2	1	3¾	3½	3	2¾
8	16¼	3	15	24	2¼	2	5¼	4¾	4¼	3¾
10	18	3½	20	27	2½	3	6½	6	5	4½
12	19½	4	25	29½	2¾	4	7½	6¾	6	5¼
14	21	4½	30	32	3	5	8¼	7½	6½	5⅞
16	22½	4½	40	36	3½	6	9	8¼	7¼	6½
18	23½	5	50	40	4	7	9¾	9	7¾	6⅞
20	24½	5	60	43	4	8	10½	9¾	8½	7½
22	26	5	70	46½	4½	9	11⅛	10¼	8¾	7⅞
24	27	5½	80	47½	4½	10	11¾	11	9½	8½
25	27½	5½	90	50	4¾	11	12¼	11⅜	9¾	8¾
26	28	5¾	100	53	5	12	13	12	10½	9¼
28	29	6	110	55½	5½	14	14	12¾	11¼	10
30	30	6	120	57	5½	16	15	13¾	12	10½
35	32½	6½	130	60¾	5¾	18	15¾	14½	12¾	11¼
40	34½	6½	150	65	6	20	16¾	15¼	13½	11¾
50	38½	7	200	74½	6	25	18½	17¼	15	13¼
60	42¼	7	250	84	6	30	20¼	19¾	16¼	14½

The *unit* of nominal power for steam engines, or the usual estimate of dynamical effect per minute of a horse, called by engineers a horse-power, is 33,000 lbs. at a velocity of 1 foot per minute; or, the effect of a load of 200 lbs. raised by a horse for 8 hours a day, at the rate of $2\frac{1}{2}$ miles per hour, or *150* lbs. at the rate of 220 feet per minute.

To estimate by means of an indicator the amount of effective power produced by a steam engine.

Rule.—Multiply the area of the piston in square inches by the average force of the steam in lbs. and by the velocity of the piston in feet per minute; divide the product by 33,000, and $\frac{7}{10}$ths of the quotient equal the effective power.

Ex. Suppose an engine with a cylinder of $37\frac{1}{2}$ inches diameter, a stroke of 7 feet, and making 17 revolutions per minute, or 238 feet velocity, and the average indicated pressure of the steam 16·73 lbs. per square inch; required the effective power.

$$\frac{\text{Area} = 1104{\cdot}4687 \text{ inches} \times 16{\cdot}73 \text{ lbs.} \times 238 \text{ feet}}{33000}$$

$$= \frac{133{\cdot}26 \times 7}{10} = 93{\cdot}282 \text{ horses' power.}$$

To determine the proper velocity for the piston of a steam engine.

Rule.—Multiply the logarithm of the *n*th part of the stroke at which the steam is cut off by 2·3, and to the product of which add ·7. Multiply the sum by the distance in feet the piston has travelled when the steam is cut off, and 120 times the square root of the product equal the proper velocity for the piston in feet per minute.

Ex. Let the steam be cut off in an 8-feet stroke when the piston has travelled $\frac{1}{4}$th of the length; required its proper velocity.

Logarithm of 4 =	0·60206
Multiplied by	2·3
	1·384738
To which add	·7
	2·084738
	2

$\sqrt{4{\cdot}169476} = 2{\cdot}04 \times 120 = 245$ feet, velocity per minute.

Table of Approximate Velocities for the Pistons of Steam Engines.

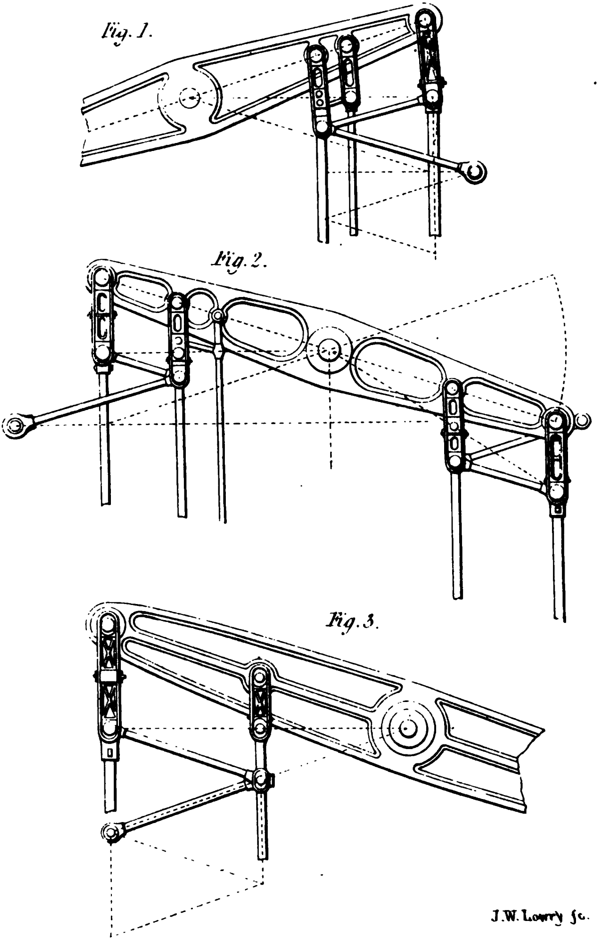
Condensing Engines.			Non-Condensing Engines.		
Length of stroke in feet.	Velocity in feet per minute.	Number of revolutions per minute.	Length of stroke in feet.	Velocity in feet per minute.	Number of revolutions per minute.
2	160	40	1½	186	62
2½	177½	35½	2	200	50
3	192	32	2½	212½	42½
3½	203	29	2¾	217¼	39½
4	214	26¾	3	222	37
4½	220½	24½	3½	231	33
5	230	23	4	236	29½
5½	236½	21½	4½	243	27
6	240	20	5	247½	24¾
7	245	17½	5½	253	23
8	256	16	6	264	22

Of the Parallel Motion in a Steam Engine.

When the power from the piston is communicated by means of a beam or lever moving upon an axis, the parallel motion becomes a very important portion of the machine, for then it forms the link of connection, and by its properties renders the action of alternate circular motion and reciprocating vertical motion mutually agreeable, thereby properly insuring to the piston-rod a truly direct line to that of the cylinder: but to effect this, the greatest degree of exactitude of the various parts is required, otherwise extra friction is created, and the effective power of the engine proportionately diminished. (See Plates E and F.)

Fig. 1, Plate E, is a motion for a double-cylinder engine.
„ 2, „ a motion for a pumping engine.
„ 3, „ the common condensing engine.

Fig. 1, Plate F, is for a marine engine.
„ 2, „ also for a marine engine.
„ 3, „ for a non-condensing or high-pressure engine.



J.W. Lowry Sc.

John Weale, 59, High Holborn 1853.

PARALLEL MOTIONS.

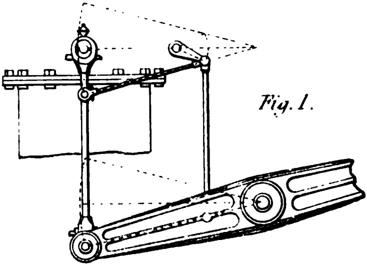


Fig. 1.

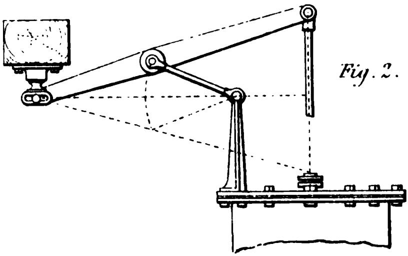
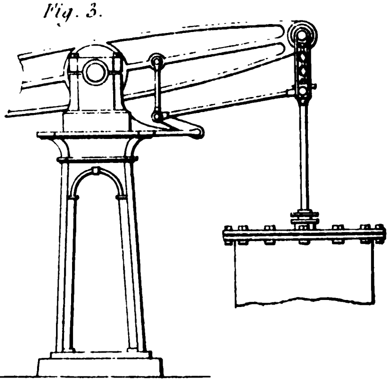


Fig. 2.

Fig. 3.



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ble by which to determine the various Distances of the Moveable Points in a Parallel Motion.

Parallel bars in ft.	Length of radius rods in ft. & in.
2	2 0
2¼	1 4⅜
2½	0 10⅞
2¾	0 6⅞
3	0 4
2	3 1½
2¼	2 3
2½	1 7¼
2¾	1 1⅜
3	0 9
3¼	0 5¾
2	4 6
2¼	3 4⅜
2½	2 6
2¾	1 10⅛
3	1 4
3¼	0 11¼
3½	0 7¾
2¼	4 8⅜
2½	3 7¼
2¾	2 9
3	2 1
3¼	1 6⅜
3½	1 1¾
3¾	0 9⅞
2¾	3 10
3	3 0
3¼	2 3⅞
3½	1 9½
3¾	1 4¼
4	1 0
4¼	0 8½

Radius of beams in ft.	Parallel bars in ft.	Length of radius rods in ft. & in.
6½ feet	3	4 1⅛
	3¼	3 3
	3½	2 6⅞
	3¾	2 0¼
	4	1 6¾
	4¼	1 2¼
	4½	0 10½
7 feet	3	5 4
	3¼	4 4
	3½	3 6
	3¾	3 2⅞
	4	2 3
	4¼	1 9
	4½	1 4⅝
	4¾	1 0⅞
	5	0 9⅝
7½ feet	3½	4 6⅞
	3¾	3 9
	4	3 0¾
	4¼	2 6
	4½	2 0
	4¾	1 7
	5	1 3
	5¼	0 11½
8 feet	3½	5 9½
	3¾	4 9¾
	4	4 0
	4¼	3 3¾
	4½	2 8⅝
	4¾	2 2¾
	5	1 9⅝
	5¼	1 5¼

Radius of beams in ft.	Parallel bars in ft.	Length of radius rods in ft. & in.
8½ feet	3¾	6 0¼
	4	5 6¾
	4¼	4 3
	4½	3 6⅝
	4¾	2 11½
	5	2 5⅜
	5¼	2 0⅛
	5½	1 7⅝
9 feet	4	6 3
	4¼	5 3¾
	4½	4 6
	4¾	3 9⅝
	5	3 2½
	5¼	2 8⅛
	5½	2 2¾
	5¾	1 10
	6	1 6
9½ feet	4½	5 6⅝
	4¾	4 9
	5	4 0⅝
	5¼	3 5⅜
	5½	2 10⅞
	5¾	2 5¼
	6	2 0½
10 feet	4¾	5 9½
	5	5 0
	5¼	4 3½
	5½	3 8⅛
	5¾	3 1¾
	6	2 8
	6¼	2 3
	6½	1 10⅛

Radius of beams in ft.	Parallel bars in ft.	Length of radius rods in ft. & in.
10½ feet	5	6 0½
	5¼	5 3
	5½	4 6½
	5¾	3 11
	6	3 3¼
	6¼	2 10¾
	6½	2 5⅜
	6¾	2 1
11 feet	5¼	6 3½
	5½	5 6
	5¾	4 9½
	6	4 2
	6¼	3 7⅜
	6½	3 1⅜
	6¾	2 8⅛
11½ feet	5½	6 6½
	5¾	5 9
	6	5 0½
	6¼	4 5
	6½	3 10⅛
	6¾	3 4
	7	2 10⅝
	7¼	2 6
12 feet	5¾	6 8¼
	6	6 0
	6¼	5 3½
	6½	4 7⅞
	6¾	4 1
	7	3 6⅞
	7¼	3 1⅝
	7½	2 8¼
	7¾	2 4

LOGARITHMS.

LOGARITHMS literally signify *ratios of numbers;* hence Logarithmic Tables may be various, but those in common use for the facilitating of arithmetical operations generally are of the following corresponding progressions, viz.

Arithmetical, 0, 1, 2, 3, &c., or series of logarithms.
Geometrical, 1, 10, 100, 1000, &c., or ratio of numbers.

And thus it may be perceived, that if the log. of 10 be 1, the log. of any number less than 10 must consist wholly of decimals, because increasing by a decimal ratio. Again, if the log. of 100 be 2, the log. of any intermediate number between 10 and 100 must be 1, with so many decimals annexed; and in like manner, the log. of any intermediate number between 100 and 1000 must be 2, with decimals annexed proportionally, as before.

APPLICATION AND UTILITY OF COMMON LOGARITHMIC TABLES.

The whole numbers of the series of logarithms, as 1, 2, 3, &c., are called the indices, or characteristics of the logarithm, and which must be added to the logarithm obtained by the Table, in proportion to the number of figures contained in the given sum. Thus, suppose the logarithm be required for a sum of only two figures, the index is 1; if of three figures, the index is 2; and if of four figures, the index is 3, &c., being always a number less by unity than the number of figures the given sum contains.

Ex. The index of 8 is 0, because it is less than 10.

The index of 80 is 1, because it is less than 100.

The index of 800 is 2, because it is less than 1000.

The index of 8000 is 3, because it is less than 10,000, &c.

The index of a decimal is always the number which denotes the significant figure from the decimal point, and is marked with the sign thus —, to distinguish it from a whole number.

Ex. The index of ·32549 is —1, because the first significant figure is the first decimal.

The index of ·032549 is —2, because the first significant figure is the second decimal.

The index of ·0032549 is —3, because the first significant figure is the third decimal, and so on, of any other sum.

If the given sum for which the logarithm is required contains or consists of both integers and decimals, the index is determined by the integer part, without having any regard to the other.

1. *To find the logarithm of any whole number under* 100.

Look for the number under N in the first page of any Logarithmic Table; then immediately on the right of it is the logarithm required, with its proper index. Thus, the log. of 64 is 1·806180, and the log. of 72 is 1·857332.

2. *To find the logarithm of any number between* 100 *and* 1000, *or any sum not exceeding* 4 *figures.*

Find the first three figures in the left-hand column of the page under N, in which the number is situated, and the fourth figure, at the top or bottom of the page; then the logarithm directly under the fourth

figure, and in a line with the three figures in the column on the left, with its proper index, is the logarithm required. Thus, the log. of 450 is 2·653213, and the log. of 7464 is 3·872972. Or, the log. of 378·5 is 2·578066, and that of ·7854 is —1·895091.

3. *To find the number indicated by a given logarithm.*

Look for the decimal part of the given logarithm in the different columns, and if it cannot be found exactly, take the next less. Then under N in the left-hand column, and in a line with the logarithm found, are three figures of the number required, and on the top of the column in which the found logarithm stands is one figure more; place the decimal point as indicated by the logarithmic index, which determines the sum, properly valued, as required.

If the logarithm cannot be found exactly in the Tables, subtract from it the next less that can be found, and divide the remainder by the tabular difference; the quotient will be the rest of the figures of the given number, which, being annexed to the tabular number already found, is the proper number required.

Ex. Required the number answering to the logarithm 3·233568.

Given logarithm	=3·233568
Next less is the log. of 1712	=3·233504
Remainder	64

$$\text{Tab. Diff.} = 253, \text{ and } \frac{64}{253} = \cdot 25$$

Hence the number required = 1712·25.

For practical purposes in mechanics, logarithms are seldom resorted to, unless for the raising of the powers of numbers or extraction of their roots: these

operations, when Tables are at hand, they very much facilitate; involution, or the raising of powers, being performed simply by multiplication; and evolution, or the extraction of roots, by division, as in simple arithmetic.

Ex. 1. Required the square or second power of 25·791.

Log. of 25·791 = 1·411468
Multiplied by 2, the power required.

Logarithm 2·822936, indicated number or square required = 665·175.

Ex. 2. What is the cube of 30·7146?

Logarithm = 1·487345
Multiplied by 3, the power required.

Logarithm 4·462035, indicated number or cube required = 28975·7.

Ex. 3. Required the square root of 365.

Log. $= \dfrac{2{\cdot}562293}{2} = 1{\cdot}281146$, indicated number or root $= 19{\cdot}105$.

Ex. 4. Find the cube root of 12345.

Log. $= \dfrac{4{\cdot}091491}{3} = 1{\cdot}363830$, indicated number or root $= 23{\cdot}1116$.

Table of Logarithms from 1 *to* 100.

N.	Log.	N.	Log.	N.	Log.	N.	Log.
1	0·000000	26	1·414973	51	1·707570	76	1·880814
2	0·301030	27	1·431364	52	1·716003	77	1·886491
3	0·477121	28	1·447158	53	1·724276	78	1·892095
4	0·602060	29	1·462398	54	1·732394	79	1·897627
5	0·698970	30	1·477121	55	1·740363	80	1·903090
6	0·778151	31	1·491362	56	1·748188	81	1·908485
7	0·845098	32	1·505150	57	1·755875	82	1·913814
8	0·903090	33	1·518514	58	1·763428	83	1·919078
9	0·954243	34	1·531479	59	1·770852	84	1·924279
10	1·000000	35	1·544068	60	1·778151	85	1·929419
11	1·041393	36	1·556303	61	1·785330	86	1·934498
12	1·079181	37	1·568202	62	1·792392	87	1·939519
13	1·113943	38	1·579784	63	1·799341	88	1·944483
14	1·146128	39	1·591065	64	1·806180	89	1·949390
15	1·176091	40	1·602060	65	1·812913	90	1·954243
16	1·204120	41	1·612784	66	1·819544	91	1·959041
17	1·230449	42	1·623249	67	1·826075	92	1·963788
18	1·255273	43	1·633468	68	1·832509	93	1·968483
19	1·278754	44	1·643453	69	1·838849	94	1·973128
20	1·301030	45	1·653213	70	1·845098	95	1·977724
21	1·322219	46	1·662758	71	1·851258	96	1·982271
22	1·342423	47	1·672098	72	1·857332	97	1·986772
23	1·361728	48	1·681241	73	1·863323	98	1·991226
24	1·380211	49	1·690196	74	1·869232	99	1·995635
25	1·397940	50	1·698970	75	1·875061	100	2·000000

Note.—The best Tables of Logarithms are those by Taylor, Gardiner, Hutton, Babbage, and Caillet. The smaller works are those by Lalande, Hassler, Renaud, Christison, and Wallace, and those published in the 'Library of Useful Knowledge.'

Tables of the Circumferences of Circles to the nearest fraction of practical measurement; also the Areas of Circles in inches and decimal parts, likewise of feet and decimal parts, as may be required.

Rules that may render the following Tables more generally useful.

1. Any of the areas in inches multiplied by ·04328, or the areas in feet multiplied by 6·232, the product is the number of imperial gallons at 1 foot in depth.

2. Any of the areas in feet multiplied by ·03704, the product equal the number of cubic yards at 1 foot in depth.

3. The area of a circle in inches multiplied by the length or thickness in inches, and by ·263, the product equal the weight in lbs. of cast iron.

Note.—The French cubic metre, or unit of solid measure, equal 35·31716 English cubic feet. Also the litre, or unit for measures of capacity, equal 61·028 English cubic inches, or about ·453 of an imperial gallon.

Dia. in inch.	Circum. in inch.	Area in sq. inch.	Side of = squ.
$\frac{1}{16}$	·196	·0030	·0554
$\frac{1}{8}$	·392	·0122	·1107
$\frac{3}{16}$	·589	·0276	·1661
$\frac{1}{4}$	·785	·0490	·2115
$\frac{5}{16}$	·981	·0767	·2669
$\frac{3}{8}$	1·178	·1104	·3223
$\frac{7}{16}$	1·374	·1503	·3771
$\frac{1}{2}$	1·570	·1963	·4331
$\frac{9}{16}$	1·767	·2485	·4995
$\frac{5}{8}$	1·963	·3068	·5438
$\frac{11}{16}$	2·159	·3712	·6093
$\frac{3}{4}$	2·356	·4417	·6646
$\frac{13}{16}$	2·552	·5185	·7200
$\frac{7}{8}$	2·748	·6013	·7754
$\frac{15}{16}$	2·945	·6903	·8308
1 in.	$3\frac{1}{8}$	·7854	$\frac{7}{8}$
$1\frac{1}{8}$	$3\frac{1}{2}$	·9940	$\frac{7}{8}$ & $\frac{3}{32}$
$1\frac{1}{4}$	$3\frac{7}{8}$	1·227	1 in.
$1\frac{3}{8}$	$4\frac{1}{4}$	1·484	$1\frac{3}{16}$
$1\frac{1}{2}$	$4\frac{5}{8}$	1·767	$1\frac{5}{16}$
$1\frac{5}{8}$	$5\frac{1}{8}$	2·074	$1\frac{7}{16}$
$1\frac{3}{4}$	$5\frac{1}{2}$	2·405	$1\frac{9}{16}$
$1\frac{7}{8}$	$5\frac{7}{8}$	2·761	$1\frac{11}{16}$
2 in.	$6\frac{1}{4}$	3·141	$1\frac{3}{4}$
$2\frac{1}{8}$	$6\frac{5}{8}$	3·546	$1\frac{7}{8}$
$2\frac{1}{4}$	7	3·976	2 in.
$2\frac{3}{8}$	$7\frac{3}{8}$	4·430	$2\frac{1}{8}$
$2\frac{1}{2}$	$7\frac{3}{4}$	4·908	$2\frac{3}{16}$
$2\frac{5}{8}$	$8\frac{1}{4}$	5·412	$2\frac{5}{16}$
$2\frac{3}{4}$	$8\frac{5}{8}$	5·939	$2\frac{7}{16}$
$2\frac{7}{8}$	9	6·491	$2\frac{9}{16}$
3 in.	$9\frac{3}{8}$	7·068	$2\frac{5}{8}$
$3\frac{1}{8}$	$9\frac{3}{4}$	7·669	$2\frac{3}{4}$
$3\frac{1}{4}$	$10\frac{1}{4}$	8·295	$2\frac{7}{8}$
$3\frac{3}{8}$	$10\frac{5}{8}$	8·946	3 in.
$3\frac{1}{2}$	11	9·621	$3\frac{1}{8}$
$3\frac{5}{8}$	$11\frac{3}{8}$	10·320	$3\frac{1}{4}$
$3\frac{3}{4}$	$11\frac{3}{4}$	11·044	$3\frac{5}{16}$
$3\frac{7}{8}$	$12\frac{1}{8}$	11·793	$3\frac{7}{16}$

Dia. in inch.	Circum. in ft.	in.	Area in sq. inch.	Area in sq. feet.	Dia. in inch.
4 in.	1	0½	12·566	·0879	9 in.
4⅛	1	0⅞	13·364	·0935	9⅛
4¼	1	1⅜	14·186	·0993	9¼
4⅜	1	1¾	15·033	·1052	9⅜
4½	1	2⅛	15·904	·1113	9½
4⅝	1	2½	16·800	·1176	9⅝
4¾	1	2⅞	17·720	·1240	9¾
4⅞	1	3¼	18·665	·1306	9⅞
5 in.	1	3⅝	19·635	·1374	10 in.
5⅛	1	4⅛	20·629	·1444	10⅛
5¼	1	4½	21·647	·1515	10¼
5⅜	1	4⅞	22·690	·1588	10⅜
5½	1	5¼	23·758	·1663	10½
5⅝	1	5⅝	24·850	·1739	10⅝
5¾	1	6	25·967	·1817	10¾
5⅞	1	6⅜	27·108	·1897	10⅞
6 in.	1	6¾	28·274	·1979	11 in.
6⅛	1	7¼	29·464	·2062	11⅛
6¼	1	7⅝	30·679	·2147	11¼
6⅜	1	8	31·919	·2234	11⅜
6½	1	8⅜	33·183	·2322	11½
6⅝	1	8¾	34·471	·2412	11⅝
6¾	1	9⅛	35·784	·2504	11¾
6⅞	1	9½	37·122	·2598	11⅞
7 in.	1	10	38·484	·2693	12 in.
7⅛	1	10⅜	39·871	·2791	12⅛
7¼	1	10¾	41·282	·2889	12¼
7⅜	1	11⅛	42·718	·2990	12⅜
7½	1	11½	44·178	·3092	12½
7⅝	1	11⅞	45·663	·3196	12⅝
7¾	2	0⅜	47·173	·3299	12¾
7⅞	2	0¾	48·707	·3409	12⅞
8 in.	2	1⅛	50·265	·3518	13 in.
8⅛	2	1½	51·848	·3629	13⅛
8¼	2	1⅞	53·456	·3741	13¼
8⅜	2	2¼	55·088	·3856	13⅜
8½	2	2⅝	56·745	·3972	13½
8⅝	2	3	58·426	·4089	13⅝
8¾	2	3⅜	60·132	·4209	13¾
8⅞	2	3⅞	61·862	·4330	13⅞

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Dia. in inch.	Circum. in ft.	in.	Area in sq. inch.	Area in sq. feet.	Dia. in inch.	Circum. in ft.	in.	Area in sq. inch.	Area in sq. feet.
4 in.	1	0½	12·566	·0879	9 in.	2	4¼	63·617	·4453
4⅛	1	0⅞	13·364	·0935	9⅛	2	4⅝	65·396	·4577
4¼	1	1⅜	14·186	·0993	9¼	2	5	67·200	·4704
4⅜	1	1¾	15·033	·1052	9⅜	2	5⅜	69·029	·4832
4½	1	2⅛	15·904	·1113	9½	2	5¾	70·882	·4961
4⅝	1	2½	16·800	·1176	9⅝	2	6¼	72·759	·5093
4¾	1	2⅞	17·720	·1240	9¾	2	6⅝	74·662	·5226
4⅞	1	3¼	18·665	·1306	9⅞	2	7	76·588	·5361
5 in.	1	3⅝	19·635	·1374	10 in.	2	7⅜	78·540	·5497
5⅛	1	4⅛	20·629	·1444	10⅛	2	7¾	80·515	·5636
5¼	1	4½	21·647	·1515	10¼	2	8¼	82·516	·5776
5⅜	1	4⅞	22·690	·1588	10⅜	2	8½	84·540	·5917
5½	1	5¼	23·758	·1663	10½	2	8⅞	86·590	·6061
5⅝	1	5⅝	24·850	·1739	10⅝	2	9⅜	88·664	·6206
5¾	1	6	25·967	·1817	10¾	2	9¾	90·762	·6353
5⅞	1	6⅜	27·108	·1897	10⅞	2	10⅛	92·855	·6499
6 in.	1	6¾	28·274	·1979	11 in.	2	10½	95·033	·6652
6⅛	1	7¼	29·464	·2062	11⅛	2	10⅞	97·205	·6804
6¼	1	7⅝	30·679	·2147	11¼	2	11¼	99·402	·6958
6⅜	1	8	31·919	·2234	11⅜	2	11¾	101·623	·7143
6½	1	8⅜	33·183	·2322	11½	3	0⅛	103·869	·7270
6⅝	1	8¾	34·471	·2412	11⅝	3	0½	106·139	·7429
6¾	1	9⅛	35·784	·2504	11¾	3	0⅞	108·434	·7590
6⅞	1	9½	37·122	·2598	11⅞	3	1¼	110·753	·7752
7 in.	1	10	38·484	·2693	12 in.	3	1⅝	113·097	·7916
7⅛	1	10⅜	39·871	·2791	12⅛	3	2	115·466	·8082
7¼	1	10¾	41·282	·2889	12¼	3	2½	117·859	·8250
7⅜	1	11⅛	42·718	·2990	12⅜	3	2⅞	120·276	·8419
7½	1	11½	44·178	·3092	12½	3	3¼	122·718	·8590
7⅝	1	11⅞	45·663	·3196	12⅝	3	3⅝	125·185	·8762
7¾	2	0⅜	47·173	·3299	12¾	3	4	127·676	·8937
7⅞	2	0¾	48·707	·3409	12⅞	3	4⅜	130·192	·9113
8 in.	2	1⅛	50·265	·3518	13 in.	3	4¾	132·732	·9291
8⅛	2	1½	51·848	·3629	13⅛	3	5¼	135·297	·9470
8¼	2	1⅞	53·456	·3741	13¼	3	5⅝	137·886	·9642
8⅜	2	2¼	55·088	·3856	13⅜	3	6	140·500	·9835
8½	2	2⅝	56·745	·3972	13½	3	6⅜	143·139	1·0019
8⅝	2	3	58·426	·4089	13⅝	3	6¾	145·802	1·0206
8¾	2	3⅜	60·132	·4209	13¾	3	7⅛	148·489	1·0294
8⅞	2	3⅞	61·862	·4330	13⅞	3	7½	151·201	1·0584

Circum. in ft.	in.	Area in sq. inch.	Area in sq. feet.	Dia. in inch.	Circum. in ft.	in.	Area in sq. inch.	Area in sq. feet.
3	7⅞	153·938	1·0775	19	4	11⅝	283·529	1·9847
3	8⅜	156·699	1·0968	19⅛	5	0	287·272	1·9941
3	8¾	159·485	1·1193	19¼	5	0½	291·039	2·0371
3	9⅛	162·295	1·1360	19⅜	5	0⅞	294·831	2·0637
3	9½	165·130	1·1569	19½	5	1¼	298·648	2·0904
3	9⅞	167·989	1·1749	19⅝	5	1⅝	302·489	2·1172
3	10¼	170·873	1·1961	19¾	5	2	306·355	2·1443
3	10¾	173·782	1·2164	19⅞	5	2⅜	310·245	2·1716
3	11⅛	176·715	1·2370	20	5	2⅞	314·160	2·1990
3	11½	179·672	1·2577	20⅛	5	3¼	318·099	2·2265
3	11⅞	182·654	1·2785	20¼	5	3⅝	322·063	2·2543
4	0¼	185·661	1·2996	20⅜	5	4	326·051	2·2822
4	0⅝	188·692	1·3208	20½	5	4⅜	330·064	2·3103
4	1	191·748	1·3422	20⅝	5	4¾	334·101	2·3386
4	1½	194·828	1·3637	20¾	5	5⅛	338·163	2·3670
4	1⅞	197·933	1·3855	20⅞	5	5½	342·250	2·3956
4	2¼	201·062	1·4074	21	5	5⅞	346·361	2·4244
4	2⅝	204·216	1·4295	21⅛	5	6⅜	350·497	2·4533
4	3	207·394	1·4517	21¼	5	6¾	354·657	2·4824
4	3⅜	210·597	1·4741	21⅜	5	7⅛	358·841	2·5117
4	3¾	213·825	1·4967	21½	5	7½	363·051	2·5412
4	4¼	217·077	1·5195	21⅝	5	7⅞	367·284	2·5708
4	4⅝	220·353	1·5424	21¾	5	8¼	371·543	2·6007
4	5	223·654	1·5655	21⅞	5	8¾	375·826	2·6306
4	5⅜	226·980	1·5888	22	5	9⅛	380·133	2·6608
4	5¾	230·330	1·6123	22⅛	5	9½	384·465	2·6691
4	6⅛	233·705	1·6359	22¼	5	9⅞	388·822	2·7016
4	6½	237·104	1·6597	22⅜	5	10¼	393·203	2·7224
4	6⅞	240·528	1·6836	22½	5	10⅝	397·608	2·7632
4	7⅜	243·977	1·7078	22⅝	5	11	402·038	2·7980
4	7¾	247·450	1·7321	22¾	5	11½	406·493	2·8054
4	8⅛	250·947	1·7566	22⅞	5	11⅞	410·972	2·8658
4	8½	254·469	1·7812	23	6	0¼	415·476	2·8903
4	8⅞	258·016	1·8061	23⅛	6	0⅝	420·004	2·9100
4	9¼	261·587	1·8311	23¼	6	1	424·557	2·9518
4	9¾	265·182	1·8562	23⅜	6	1⅜	429·135	2·9937
4	10⅛	268·803	1·8816	23½	6	1¾	433·737	3·0129
4	10½	272·447	1·9071	23⅝	6	2¼	438·363	3·0261
4	10⅞	276·117	1·9328	23¾	6	2⅝	443·014	3·072
4	11¼	279·811	1·9586	23⅞	6	3	447·690	3·10

Dia. in ft.	in.	Circum. in ft.	in.	Area in sq. inch.	Area in sq. feet.	Dia. in ft.	in.	Circum. in ft.	in.	Area in sq. inch.	Area in sq. feet.
2	0	6	3⅜	452·390	3·1418	2	10	8	10¾	907·922	6·3051
2	0¼	6	4⅛	461·864	3·2075	2	10¼	8	11½	921·328	6·3981
2	0½	6	4⅞	471·436	3·2731	2	10½	9	0⅜	934·822	6·4911
2	0¾	6	5¾	481·106	3·3410	2	10¾	9	1⅛	948·419	6·5863
2	1	6	6½	490·875	3·4081	2	11	9	1⅞	962·115	6·6815
2	1¼	6	7¼	500·741	3·4775	2	11¼	9	2¾	975·908	6·7772
2	1½	6	8⅛	510·706	3·5468	2	11½	9	3½	989·800	6·8738
2	1¾	6	8⅞	520·769	3·6101	2	11¾	9	4¼	1003·79	6·9701
2	2	6	9⅝	530·930	3·6870	3	0	9	5	1017·87	7·0688
2	2¼	6	10½	541·189	3·7583	3	0¼	9	5⅞	1032·06	7·1671
2	2½	6	11¼	551·547	3·8302	3	0½	9	6⅝	1046·35	7·2664
2	2¾	7	0	562·002	3·9042	3	0¾	9	7½	1060·73	7·3662
2	3	7	0¾	572·556	3·9761	3	1	9	8¼	1075·21	7·4661
2	3¼	7	1⅝	583·208	4·0500	3	1¼	9	9	1089·79	7·5671
2	3½	7	2⅜	593·958	4·1241	3	1½	9	9⅞	1104·46	7·6691
2	3¾	7	3⅛	604·807	4·2000	3	1¾	9	10⅝	1119·24	7·7791
2	4	7	3⅞	615·753	4·2760	3	2	9	11⅜	1134·12	7·8681
2	4¼	7	4¾	626·798	4·3521	3	2¼	10	0⅛	1149·09	7·9791
2	4½	7	5½	637·941	4·4302	3	2½	10	0⅞	1164·16	8·0846
2	4¾	7	6¼	649·182	4·5083	3	2¾	10	1¾	1179·32	8·1891
2	5	7	7	660·521	4·5861	3	3	10	2½	1194·59	8·2951
2	5¼	7	7⅞	671·958	4·6665	3	3¼	10	3¼	1209·95	8·4026
2	5½	7	8⅝	683·494	4·7467	3	3½	10	4	1225·42	8·5091
2	5¾	7	9½	695·128	4·8274	3	3¾	10	4⅞	1240·98	8·6171
2	6	7	10¼	706·860	4·9081	3	4	10	5⅝	1256·64	8·7269
2	6¼	7	11	718·690	4·9901	3	4¼	10	6⅜	1272·39	8·8361
2	6½	7	11¾	730·618	5·0731	3	4½	10	7¼	1288·25	8·9462
2	6¾	8	0⅝	742·644	5·1573	3	4¾	10	8	1304·20	9·0561
2	7	8	1⅜	754·769	5·2278	3	5	10	8¾	1320·25	9·1686
2	7¼	8	2⅛	766·992	5·3264	3	5¼	10	9½	1336·40	9·2112
2	7½	8	2⅞	779·313	5·4112	3	5½	10	10⅜	1352·65	9·3936
2	7¾	8	3¾	791·732	5·4982	3	5¾	10	11⅛	1369·00	9·5061
2	8	8	4½	804·249	5·5850	3	6	10	11⅞	1385·44	9·6212
2	8¼	8	5⅜	816·865	5·6729	3	6¼	11	0¾	1401·98	9·7364
2	8½	8	6⅛	829·578	5·7601	3	6½	11	1½	1418·62	9·8518
2	8¾	8	6⅞	842·390	5·8491	3	6¾	11	2¼	1435·36	9·9671
2	9	8	7⅝	855·300	5·9398	3	7	11	3	1452·20	10·084
2	9¼	8	8½	868·308	6·0291	3	7¼	11	3⅞	1469·14	10·202
2	9½	8	9¼	881·415	6·1201	3	7½	11	4⅝	1486·17	10·3[illegible]
2	9¾	8	10	894·619	6·2129	3	7¾	11	5⅜	1503·30	10·[illegible]

Dia. in ft.	in.	Circum. in ft.	in.	Area in sq. inch.	Area in sq. feet.	Dia. in ft.	in.	Circum. in ft.	in.	Area in sq. inch.	Area in sq. feet.
	8	11	6¼	1520·53	10·559	4	6	14	1⅝	2290·22	15·904
	8¼	11	7	1537·86	10·679	4	6¼	14	2⅜	2311·48	16·051
	8½	11	7¾	1555·28	10·800	4	6½	14	3¼	2332·83	16·200
	8¾	11	8½	1572·81	10·922	4	6¾	14	4	2354·28	16·349
	9	11	9⅜	1590·43	11·044	4	7	14	4¾	2375·83	16·498
	9¼	11	10⅛	1608·15	11·167	4	7¼	14	5½	2397·48	16·649
	9½	11	10⅞	1625·97	11·291	4	7½	14	6⅜	2419·22	16·800
	9¾	11	11¾	1643·89	11·415	4	7¾	14	7⅛	2441·07	16·951
	10	12	0½	1661·90	11·534	4	8	14	7⅞	2463·01	17·104
	10¼	12	1¼	1680·02	11·666	4	8¼	14	8⅝	2485·05	17·257
	10½	12	2	1698·23	11·793	4	8½	14	9½	2507·19	17·411
	10¾	12	2⅞	1716·54	11·920	4	8¾	14	10¼	2529·42	17·565
	11	12	3⅝	1734·94	12·048	4	9	14	11	2551·76	17·720
	11¼	12	4⅜	1753·45	12·176	4	9¼	14	11⅞	2574·19	17·876
	11½	12	5¼	1772·05	12·305	4	9½	15	0⅝	2596·72	18·033
	11¾	12	6	1790·76	12·435	4	9¾	15	1⅜	2619·35	18·189
4	0	12	6¾	1809·56	12·566	4	10	15	2¼	2642·08	18·347
4	0¼	12	7½	1828·46	12·697	4	10¼	15	2⅞	2664·91	18·506
4	0½	12	8⅜	1847·45	12·829	4	10½	15	3¾	2687·83	18·665
4	0¾	12	9⅛	1866·55	12·962	4	10¾	15	4½	2710·85	18·825
4	1	12	9⅞	1885·74	13·095	4	11	15	5¼	2733·97	18·985
4	1¼	12	10¾	1905·03	13·229	4	11¼	15	6⅛	2757·19	19·147
4	1½	12	11½	1924·42	13·364	4	11½	15	6⅞	2780·51	19·309
4	1¾	13	0¼	1943·91	13·499	4	11¾	15	7¾	2803·92	19·471
4	2	13	1	1963·50	13·635	5	0	15	8½	2827·44	19·635
4	2¼	13	1⅞	1983·18	13·772	5	0¼	15	9¼	2851·05	19·798
4	2½	13	2⅝	2002·96	13·909	5	0½	15	10	2874·76	19·963
4	2¾	13	3⅜	2022·84	14·047	5	0¾	15	10¾	2898·56	20·128
4	3	13	4¼	2042·82	14·186	5	1	15	11⅝	2922·47	20·294
4	3¼	13	5	2062·90	14·325	5	1¼	16	0⅜	2946·47	20·461
4	3½	13	5¾	2083·07	14·465	5	1½	16	1¼	2970·57	20·629
4	3¾	13	6½	2103·35	14·606	5	1¾	16	1⅞	2994·77	20·797
4	4	13	7⅜	2123·72	14·748	5	2	16	2¾	3019·07	20·965
4	4¼	13	8⅛	2144·19	14·890	5	2¼	16	3½	3043·47	21·135
4	4½	13	8⅞	2164·75	15·033	5	2½	16	4¼	3067·96	21·305
4	4¾	13	9¾	2185·42	15·176	5	2¾	16	5⅛	3092·56	21·476
4	5	13	10½	2206·18	15·320	5	3	16	5⅞	3117·25	21·647
4	5¼	13	11¼	2227·05	15·465	5	3¼	16	6¾	3142·04	21·819
	5½	14	0	2248·01	15·611	5	3½	16	7½	3166·92	21·992
	5¾	14	0⅞	2269·06	15·757	5	3¾	16	8¼	3191·91	22·1

Dia. in ft. in.	Circum. in ft. in.	Area in sq. inch.	Area in sq. feet.	Dia. in ft. in.	Circum. in ft. in.	Area in sq. inch.	Area in sq. feet.
5 4	16 9	3216·99	22·333	6 2	19 4½	4300·85	29·867
5 4¼	16 9¾	3242·17	22·515	6 2¼	19 5¼	4329·95	30·069
5 4½	16 10⅝	3267·46	22·621	6 2½	19 6	4359·16	30·271
5 4¾	16 11⅜	3292·83	22·866	6 2¾	19 6¾	4388·47	30·475
5 5	17 0⅛	3318·31	23·043	6 3	19 7⅝	4417·87	30·679
5 5¼	17 0⅞	3343·88	23·221	6 3¼	19 8⅜	4447·37	30·884
5 5½	17 1¾	3369·56	23·330	6 3½	19 9⅛	4476·97	31·090
5 5¾	17 2½	3395·33	23·578	6 3¾	19 9⅞	4506·67	31·296
5 6	17 3⅜	3421·20	23·758	6 4	19 10¾	4536·47	31·503
5 6¼	17 4⅛	3447·16	23·938	6 4¼	19 11½	4566·36	31·710
5 6½	17 4⅞	3473·23	24·119	6 4½	20 0¼	4596·35	31·919
5 6¾	17 5⅝	3499·39	24·301	6 4¾	20 1⅛	4626·44	32·114
5 7	17 6½	3525·66	24·483	6 5	20 1⅞	4656·63	32·337
5 7¼	17 7¼	3552·01	24·666	6 5¼	20 2⅝	4686·92	32·548
5 7½	17 8	3578·47	24·850	6 5½	20 3½	4717·30	32·759
5 7¾	17 8¾	3605·03	25·034	6 5¾	20 4¼	4747·79	32·970
5 8	17 9⅝	3631·68	25·220	6 6	20 5	4778·37	33·183
5 8¼	17 10⅜	3658·44	25·405	6 6¼	20 5¾	4809·05	33·396
5 8½	17 11⅛	3685·29	25·592	6 6½	20 6½	4839·83	33·619
5 8¾	17 11⅞	3712·24	25·779	6 6¾	20 7⅜	4870·70	33·824
5 9	18 0¾	3739·28	25·964	6 7	20 8⅛	4901·68	34·039
5 9¼	18 1½	3766·43	26·155	6 7¼	20 8⅞	4932·75	34·255
5 9½	18 2¼	3793·67	26·344	6 7½	20 9¾	4963·92	34·471
5 9¾	18 3⅛	3821·02	26·534	6 7¾	20 10½	4995·19	34·688
5 10	18 3⅞	3848·46	26·725	6 8	20 11¼	5026·26	34·906
5 10¼	18 4⅝	3875·99	26·916	6 8¼	21 0⅛	5058·02	35·125
5 10½	18 5½	3903·63	27·108	6 8½	21 0⅞	5089·58	35·344
5 10¾	18 6¼	3931·36	27·301	6 8¾	21 1⅝	5121·24	35·564
5 11	18 7	3959·20	27·494	6 9	21 2⅜	5153·00	35·784
5 11¼	18 7¾	3987·13	27·688	6 9¼	21 3¼	5184·86	36·006
5 11½	18 8⅝	4015·16	27·883	6 9½	21 4	5216·82	36·227
5 11¾	18 9⅜	4043·28	28·078	6 9¾	21 4¾	5248·87	36·450
6 0	18 10⅛	4071·51	28·274	6 10	21 5½	5281·02	36·674
6 0¼	18 10⅞	4099·83	28·471	6 10¼	21 6⅜	5313·27	36·897
6 0½	18 11¾	4128·25	28·668	6 10½	21 7⅛	5345·62	37·122
6 0¾	19 0½	4156·77	28·866	6 10¾	21 7⅞	5378·07	37·347
6 1	19 1¼	4185·39	29·065	6 11	21 8¾	5410·62	37·573
6 1¼	19 2⅛	4214·11	29·264	6 11¼	21 9½	5443·26	37·70[illegible]
6 1½	19 2⅞	4242·92	29·466	6 11½	21 10¼	5476·00	38·0[illegible]
6 1¾	19 3⅝	4271·83	29·665	6 11¾	21 11	5508·84	38·[illegible]

Dia. in ft. & in.	Circum. in ft. and in.	Area in feet.	Dia. in ft. & in.	Circum. in ft. and in.	Area in feet.
7 0	21 11⅞	38·4846	10 0	31 5	78·5400
1	22 3	39·4060	1	31 8⅛	79·8540
2	22 6⅛	40·3388	2	31 11¼	81·1795
3	22 9¼	41·2825	3	32 2⅜	82·5160
4	23 0⅜	42·2367	4	32 5½	83·8627
5	23 2⅛	43·2022	5	32 8⅝	85·2211
6	23 6¾	44·1787	6	32 11¾	86·5903
7	23 11	45·1656	7	33 2⅞	87·9697
8	24 1⅛	46·1638	8	33 6⅛	89·3608
9	24 4⅛	47·1730	9	33 9¼	90·7627
10	24 7¼	48·1926	10	34 0⅜	92·1749
11	24 10⅜	49·2236	11	34 3½	93·5986
8 0	25 1½	50·2656	11 0	34 6⅝	95·0334
1	25 4⅝	51·3178	1	34 9¾	96·4783
2	25 7⅞	52·3816	2	35 0⅞	97·9347
3	25 11	53·4562	3	35 4⅛	99·4021
4	26 2⅛	54·5412	4	35 7¼	100·8797
5	26 5¼	55·6377	5	35 10⅜	102·3689
6	26 8⅜	56·7451	6	36 1½	103·8691
7	26 11½	57·8628	7	36 4½	105·3794
8	27 2¾	58·9920	8	36 7¾	106·9013
9	27 5¾	60·1321	9	36 10⅞	108·4342
10	27 9	61·2826	10	37 2¾	109·9772
11	28 0⅛	62·4445	11	37 5¼	111·5319
9 0	28 3¼	63·6174	12 0	37 8⅜	113·0976
1	28 6⅜	64·8006	1	37 11½	114·6732
2	28 9½	65·9951	2	38 2⅝	116·2607
3	29 0⅝	67·2007	3	38 5¾	117·8590
4	29 3¾	68·4166	4	38 8⅞	119·4674
5	29 7	69·6440	5	39 0	121·0876
6	29 10⅛	70·8823	6	39 3¼	122·7187
7	30 1¼	72·1309	7	39 6⅜	124·3598
8	30 4⅜	73·3910	8	39 9½	126·0127
9	30 7½	74·6620	9	40 0⅝	127·6765
10	30 11⅝	75·9433	10	40 3¾	129·3504
11	31 1¾	77·2362	11	40 6⅞	131·0360

Dia. in ft. & in.	Circum. in ft. and in.	Area in feet.	Dia. in ft. & in.	Circum. in ft. and in.
13 0	40 10	132·7326	16 0	50 3⅛
1	41 1⅛	134·4391	1	50 6¼
2	41 4⅜	136·1574	2	50 9⅝
3	41 7½	137·8867	3	51 0½
4	41 10⅝	139·6260	4	51 3¾
5	42 1⅝	141·3771	5	51 6½
6	42 4⅞	143·1391	6	51 10
7	42 8	144·9111	7	52 1⅛
8	42 11⅛	146·6949	8	52 4¼
9	43 2¼	148·4896	9	52 7⅜
10	43 5½	150·2943	10	52 10½
11	43 8⅝	152·1109	11	53 1⅝
14 0	43 11¾	153·9384	17 0	53 4⅞
1	44 2⅞	155·7758	1	53 8
2	44 6	157·6250	2	53 11⅛
3	44 9⅛	159·4852	3	54 2⅛
4	45 0¼	161·3553	4	54 5⅜
5	45 3½	163·2373	5	54 8½
6	45 6⅝	165·1303	6	54 11⅝
7	45 9¾	167·0331	7	55 2⅞
8	46 0⅞	168·9479	8	55 6
9	46 4	170·8735	9	55 9⅛
10	46 7⅛	172·8091	10	56 0¼
11	46 11¼	174·7565	11	56 3½
15 0	47 1½	176·7150	18 0	56 6½
1	47 4⅝	178·6832	1	56 9⅝
2	47 7¾	180·6634	2	57 0⅞
3	47 10⅞	182·6545	3	57 4
4	48 2½	184·6555	4	57 7⅛
5	48 5⅛	186·6684	5	57 10¼
6	48 8¼	188·6923	6	58 1⅜
7	48 11⅜	190·7260	7	58 4½
8	49 2⅝	192·7716	8	58 7⅝
9	49 5¾	194·8282	9	58 10¾
10	49 8⅞	196·8946	10	59 2
11	50 0	198·9730	11	59 5⅛

No.	S. R.	C. R.	No.	S. R.	C. R.	No.	S. R.	C. R.	No.	S. R.	C. R.
1	1·0000	1·0000	55	7·4161	3·8029	109	10·4403	4·7768	163	12·7671	5·4625
2	1·4142	1·2599	56	7·4833	3·8258	110	10·4880	4·7914	164	12·8062	5·4737
3	1·7320	1·4422	57	7·5498	3·8485	111	10·5356	4·8058	165	12·8452	5·4848
4	2·0000	1·5874	58	7·6157	3·8708	112	10·5830	4·8202	166	12·8840	5·4958
5	2·2360	1·7099	59	7·6811	3·8929	113	10·6301	4·8345	167	12·9228	5·5068
6	2·4494	1·8171	60	7·7459	3·9148	114	10·6770	4·8488	168	12·9614	5·5178
7	2·6457	1·9129	61	7·8102	3·9364	115	10·7238	4·8629	169	13·0000	5·5287
8	2·8284	2·0000	62	7·8740	3·9578	116	10·7703	4·8769	170	13·0384	5·5396
9	3·0000	2·0800	63	7·9372	3·9790	117	10·8166	4·8909	171	13·0766	5·5504
10	3·1622	2·1544	64	8·0000	4·0000	118	10·8627	4·9048	172	13·1148	5·5612
11	3·3166	2·2239	65	8·0622	4·0207	119	10·9087	4·9186	173	13·1529	5·5720
12	3·4641	2·2894	66	8·1240	4·0412	120	10·9544	4·9324	174	13·1909	5·5827
13	3·6055	2·3513	67	8·1853	4·0615	121	11·0000	4·9460	175	13·2287	5·5934
14	3·7416	2·4101	68	8·2462	4·0816	122	11·0453	4·9596	176	13·2664	5·6040
15	3·8729	2·4662	69	8·3066	4·1015	123	11·0905	4·9731	177	13·3041	5·6146
16	4·0000	2·5198	70	8·3666	4·1212	124	11·1355	4·9866	178	13·3416	5·6252
17	4·1231	2·5712	71	8·4261	4·1408	125	11·1803	5·0000	179	13·3790	5·6357
18	4·2426	2·6207	72	8·4852	4·1601	126	11·2249	5·0132	180	13·4164	5·6462
19	4·3588	2·6684	73	8·5440	4·1793	127	11·2694	5·0265	181	13·4536	5·6566
20	4·4721	2·7144	74	8·6023	4·1983	128	11·3137	5·0396	182	13·4907	5·6670
21	4·5825	2·7589	75	8·6602	4·2171	129	11·3578	5·0527	183	13·5277	5·6774
22	4·6904	2·8020	76	8·7177	4·2358	130	11·4017	5 0657	184	13·5646	5·6877
23	4·7958	2·8438	77	8·7749	4·2543	131	11·4455	5·0787	185	13·6014	5·6980
24	4·8989	2·8844	78	8·8317	4·2726	132	11·4891	5·0916	186	13·6381	5·7082
25	5·0000	2·9240	79	8·8881	4·2908	133	11·5325	5·1044	187	13·6747	5·7184
26	5·0990	2·9624	80	8·9442	4·3088	134	11·5758	5·1172	188	13·7113	5·7286
27	5·1961	3·0000	81	9·0000	4·3267	135	11·6189	5·1299	189	13·7477	5·7387
28	5·2915	3·0365	82	9·0553	4·3444	136	11·6619	5·1425	190	13·7840	5·7488
29	5·3851	3·0723	83	9·1104	4·3620	137	11·7046	5·1551	191	13·8202	5·7589
30	5·4772	3·1072	84	9·1651	4·3795	138	11·7473	5·1676	192	13·8564	5·7689
31	5·5677	3·1413	85	9·2195	4·3968	139	11·7898	5·1801	193	13·8924	5·7789
32	5·6568	3·1748	86	9·2736	4·4140	140	11·8321	5·1924	194	13·9283	5·7889
33	5·7445	3·2075	87	9·3273	4·4310	141	11·8743	5·2048	195	13·9642	5·7988
34	5·8309	3·2396	88	9·3808	4·4479	142	11·9163	5·2171	196	14·0000	5·8087
35	5·9160	3·2710	89	9·4339	4·4647	143	11·9582	5·2293	197	14·0356	5·8186
36	6·0000	3·3019	90	9·4868	4·4814	144	12·0000	5·2414	198	14·0712	5·8284
37	6·0827	3·3322	91	9·5393	4·4979	145	12·0415	5·2535	199	14·1067	5·8382
38	6·1644	3·3619	92	9·5916	4·5143	146	12·0830	5·2656	200	14·1421	5·8480
39	6·2449	3·3912	93	9·6436	4·5306	147	12·1243	5·2776	201	14·1774	5·8577
40	6·3245	3·4199	94	9·6953	4·5468	148	12·1655	5·2895	202	14·2126	5·8674
41	6·4031	3·4482	95	9·7467	4·5629	149	12·2065	5·3014	203	14·2478	5·8771
42	6·4807	3·4760	96	9·7979	4·5788	150	12·2474	5·3132	204	14·2828	5·8867
43	6·5574	3·5033	97	9·8488	4·5947	151	12·2882	5·3250	205	14·3178	5·8963
44	6·6332	3·5303	98	9·8994	4·6104	152	12·3288	5·3368	206	14·3527	5·9059
45	6·7082	3·5568	99	9·9498	4·6260	153	12·3693	5·3484	207	14·3874	5·9154
46	6·7828	3·5830	100	10 0000	4·6415	154	12·4096	5·3601	208	14·4222	5·9249
47	6·8556	3·6088	101	10·0498	4·6570	155	12·4498	5·3716	209	14·4568	5·9344
48	6·9282	3·6342	102	10·0995	4·6723	156	12·4899	5·3832	210	14·4913	5·9439
49	7·0000	3·6593	103	10·1488	4·6875	157	12·5299	5·3946	211	14·5258	5·9533
50	7·0710	3·6840	104	10·1980	4·7026	158	12·5698	5·4061	212	14·5602	5·9627
51	7·1414	3·7084	105	10·2469	4·7176	159	12·6095	5·4175	213	14·5945	5·9720
52	7·2111	3·7325	106	10·2956	4·7326	160	12·6491	5·4288	214	14·6287	5·9814
53	7·2801	3·7562	107	10·3440	4·7474	161	12·6885	5·4401	215	14·6628	5·9907
54	7·3484	3·7797	108	10·3923	4·7622	162	12·7279	5·4513	216	14·6969	6·0000

To find the square or cube root of a number consisting of integers and decimals.—Rule. **Multiply the difference between the root of the integer part of the given number, and the root of the next higher number, by the decimal part of the given number, and add the product to the root of the given integer number; the sum is the root required.**

Ex. **Required the square root of 20·321.**

Square root of 21 = 4·5825
Do. 20 = 4·4721
Diff. = ·1104 × ·321 + 4·4721 = 4·507, &c., the root required.

PER-CENTAGE AND DISCOUNT TABLE.

Rate per cent.	Rate per £. in shillings.	Rate per s. in pence.	Rate per cent.	Rate per £. in shillings.	Rate per s. in pence.
⅛	·025	·015	5½	1·1	·66
¼	·05	·03	6	1·2	·72
½	·1	·06	6¼	1·25	·75
¾	·15	·09	7½	1·5	·9
1	·2	·12	8¾	1·75	1·05
2	·4	·24	10	2	1·2
2½	·5	·3	12½	2·5	1·5
3	·6	·36	15	3	1·8
3½	·7	·42	20	4	2·4
4	·8	·48	25	5	3
4½	·9	·54	30	6	3·6
5	1	·6	40	8	4·8
To cover a discount of	**Mult. the net price by**	**Divide the product by**	**To cover a discount of**	**Mult. the net price by**	**Divide the product by**
5 p. ct.	20	19	27½ p.ct.	40	29
7½	40	37	30	10	7
10	10	9	32½	40	27
12½	8	7	35	20	13
15	20	17	37½	8	5
17½	40	33	40	5	3
20	5	4	42½	40	23
22½	40	31	45	20	11
25	4	3	47½	40	21

For 50 per cent., double the sum.

Ex. 1. Required the per-centage on £127 at 3½ per cent.
127 × ·7 = 88·9 shillings, or £4. 8*s.* 10⅘*d.*

Ex. 2. What is the per-centage on 36 shillings at 2½ per cent.?
36 × ·3 = 10·8 pence, or 10 pence and 3 farthings nearly.

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of Boilers employed in the British Steam Navy, in half-morocco, price £3. 13*s*. 6*d*.

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		Plates.	Wood-cuts.
Vol. I.	Locomotive Engines	41	55
II.	Marine Engines	85	51
III.	Stationary Engines, Pumping Engines, Engines for Flour-Mills, Examples of Boilers, &c., &c.	100	58
	Total . . .	226	164

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The measuring, &c., edited by EDWARD DOBSON, Architect and Surveyor. Second Edition, with the additions on Design by E. LACY GARBETT, Architect.

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